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Construction Engineering Research Laboratory

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Center for the Advancement of Sustainability Innovations (CASI)

Proceedings of the Military Applications for Emerging Water Use Technologies Workshop

Richard J. Scholze, Gary L. Gerdes, William D. Goran, John Hall, Kurt Preston, Malcolm McLeod, David Sheets, and Richard Sustich

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Final Report

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Abstract: This first ever Military Applications for Emerging Water Use Technologies workshop gathered Department of Defense (DOD), academic, trade association, and other government subject matter experts to explore the topic of water for the military at the installation and forward operating levels. The goals of this workshop were to share information, spread visibility on current efforts, explore the potential of existing, emerging, and future technologies and other options for military installations and potentially identify potential thrust areas where demonstrations and future research can be focused. The military has many water-related requirements and goals that are applicable to DOD installations and forward facilities, as exemplified by the fiscal year 2007 (FY07) Army Environmental Requirements and Technology Assessments (AERTA, included in Appendix A to this report), which identified sustainable water usage as the top-ranked environmental requirement for the Army. Workshop participants concluded that there are a great number of issues and constraints impacting water use at both forward and fixed installations and large potential for research and demonstrations that can be used to reduce the "water footprint" of the military and migrate towards more sustainable use of this vital resource.

Executive Summary

In fiscal year 2007 (FY07), the Army Environmental Requirements and Technology Assessments (AERTA) process identified sustainable water use as its top-ranked priority. A user need was identified for the capability to recycle/reuse available water through a variety of innovative ideas and practical applications within buildings and processes including cascade recycling and water harvesting, with the ultimate purpose of increasing available supply.

Concern over water supply is emerging as a major consideration in determining whether the Department of Defense (DOD) can actively pursue its missions to best advantage while shifting troops, equipment, and resources around the country with minimum impact on local regions competing for the same water supply.

Water is often a limited, strategic resource and can impact whether an installation can expand or perform its assigned or additional missions and maintain quality of life. Communities surrounding, upstream, and downstream of military installations are also expanding and can limit the amount of water available for installations. Additionally, there are demands within base camps and theater environments where the value of water may exceed that of fuel, encouraging the application of comprehensive recycle systems and other innovations to expand water accessibility.

Nearly all surface waters have been allocated for use, making it difficult to get increased allotments; groundwater extraction occurs faster than recharge; and contamination or degradation is occurring or threatened in many areas. Droughts and water restrictions are no longer limited to arid and semi-arid regions of the country. Federal requirements mandate best management water conservation practices. The cost of water and wastewater service is constantly escalating.

The Armed Forces spends millions of dollars per year for water and wastewater services. While the military has instituted many water-conserving measures, substantial opportunities remain. Recycling and reusing water enables maximum efficiency from an available water supply and will enable installations to meet their long-term sustainability goals.

Savings of millions of dollars and billions of gallons of water per year are achievable.

A number of key policy or regulatory drivers supported the AERTA top designation:

- Installation Sustainability Plans of individual Military Installations.
- Energy Policy Act.
- Strategic Plan for Army Sustainability.
- Army Environmental Policy.
- Army Strategy for the Environment.
- Executive Order 13423.
- Army Energy and Water Campaign Plan for Installations.
- Clean Water Act.
- U.S. Army Corps of Engineers (USACE) Campaign Plan.

To address those needs and requirements, co-sponsors organized a tri-service venue, the first Military Applications for Emerging Water Use Technologies workshop. The workshop was held in Urbana, IL over a 3-day period during which subject matter experts and government stakeholders gave presentations, shared information and participated in discussion groups to explore the future of water use technologies at DOD installations and to develop potential research and demonstration needs to further the implementation of water technologies. The focus was on water access, conservation, and reuse. Fifty-eight attendees participated, from the Army, Navy, and Air Force, other Federal and Government agencies, trade groups, universities, and the private sector.

The objectives of this workshop were to share information, to spread visibility of current efforts, to explore potential water-related interest areas for the DOD (both fixed installations and forward operating facilities), and to potentially identify future research and demonstration areas.

A number of facilitated breakout sessions were scheduled during the 3-day period to develop research needs. The freewheeling discussions during the workshop provided a number of ideas along with constraints and background information necessary to support sustainable water use at military installations and forward operating facilities while raising the level of awareness of what is occurring in the research and application community outside of military installations.

The two main workshop foci were on forward operating bases and fixed facilities. The following sections summarize the findings.

Findings for forward operating facilities

1. It was the group consensus that water management at forward facilities can be improved by:
    - Implementing treatment and reuse at point of use, and cascade re-use.
    - Implementing water conservation measures.
    - Using alternative and innovative water sources.
    - Implementing technologies that are expandable, making increases in camp size and transition to long term operations more seamless.
    - Using a systems approach to base camp design and operation.
    - Using appropriately trained personnel for base camp design and operation.
    - Having an organization assume ownership of forward facilities.

2. There was discussion of specific needed technologies, of which the following are being addressed by Research, Development, and Engineering Command (RDECOM), the Office of Naval Research, Sandia National Labs, and Water CAMPWS:
    - Improving treatment provided by the existing reverse osmosis water purification unit (ROWPU) — all of the above mentioned organizations are involved in research to improve membrane treatment and/or research to develop next generation deployable systems.
    - RDECOM is developing a "lab on a chip" for immediate analysis of water samples.

3. Other needed technologies not specifically addressed by the presenters included:
    - Stormwater treatment system.
    - Rapid start-up bioreactors.
    - Separate treatment for wastewater solids.
    - Recover energy from wastewater and water bottles.

4. All three breakout groups agreed that a base camp water technology demonstration site was needed.

The costs for the security and energy resources to transport water are staggering. More important is the risk of soldier casualties when transporting water across unsecured areas. The most important goal to improve the management of water at forward facilities is to reduce the amount of water being hauled by tanker trucks from a water source to a base camp. This must be accomplished by water reuse, water conservation, and the use of non-conventional water sources. The way forward must focus on these things.

Because there is a direct relationship between energy and water, the way forward must also focus on reducing the energy needed in water management. The water resource itself is usually inexpensive, if not free. But a significant amount of energy is necessary to treat raw water; transport and distribute the treated water to users; and cool the water for drinking. Wastewater treatment is also energy intensive. Clearly, to decrease the cost of water in theatre, the amount of energy needed to manage water must be decreased.

The following topics were identified with additional supporting information to be found in the appropriate chapter:

1. Innovative sources of water must be exploited.
2. Water reuse technologies must be developed. Much work has been done, but resources are still needed to demonstrate newly developed but unproven technologies, to continue the development of new and promising technologies, and to conduct basic research that will lead to new technology or make existing technology more practical.
3. Implementation of water conservation/water efficiency technology and techniques, where applicable, including irrigation related options.
4. There is much on-going work to improve current water management technology by reducing energy demand. Even as membrane treatment problems are being addressed, alternative treatment scenarios should also be considered, at both the basic and applied research levels.
5. Improve energy efficiency of heat transfer when heating and cooling water.

Findings for fixed facilities

1. An installation needs a balance of potable and nonpotable water and a balance of investment/resources/manpower to meet its mission requirements. With the military command structure, an appropriate emphasis can drive the forces of change and increase the speed of implementation. A primary difference between fixed and forward facilities is the cost to de-

liver product water, the dollars per gallon for forward facilities vs. dollars per kgal (thousands of gallons) in fixed facilities (where efficiencies of scale exist).

2. A need to know where and how water is used on installations and the requisite quality. Tools and methodologies exist but are not implemented.
3. There was an agreement that demonstrations of emerging technology and existing technology would be useful to show other installations both the feasibility and cost/benefit considerations for implementation at their locations. These could be concentrated at one location or spread around with appropriate technology transfer mechanisms. Representative topics include: stormwater and rainwater harvesting, leak control, graywater reuse, changes in irrigation through advanced technology, changes in plant selection and landscaping using xeriscaping and zeroscaping, advanced cooling tower treatment, aquifer storage and recharge, and riverbank filtration. There needs to be a way to encourage adoption through the construction, design-build, and implementation stages of projects. Stormwater especially is an untapped resource and should be used where appropriate. The tenets of Low Impact Development (LID) and Leadership in Energy and Environmental Design (LEED) should be encouraged to support sustainability.

Numerous research and demonstration topics and technologies were identified that will support fixed installations. The presentations and white papers identify many of them. Research is ongoing throughout the United States and the world and it is essential to maintain awareness and to be able to adapt and adopt technologies to support water needs at fixed facilities. The following areas consolidate possibilities for research and demonstration:

1. Water and energy are closely linked. Water use technologies are needed that reduce the energy demand, and energy and power technologies are needed that reduce the water demand.
2. Water should be treated to match its intended use. Water treatment and distribution technologies, including point-of-use, are needed that affordably provide options for water treatment to be closely matched to intended water use, while still protecting users from potential unsafe uses of water.
3. Engineering improvements are available now to improve water conservation, meet low-impact development requirements, improve irrigation and reduce input requirements in forward and fixed facilities. The military needs to invest to evaluate and demonstrate these capabilities for wider use in military operations.

4. Water technologies and techniques should be explored that limit input of both water and energy, e.g., through increased efficiency in operations and maintenance, reduction of amount of energy to produce a given amount of water, and improved materials.
5. Water "budgets" are needed to better understand current water uses and losses in both fixed and forward operations. Future infrastructure enhancements should provide for water reuse options, multiple water treatment/distribution networks, and the collection and reuse of rainwater and stormwater for buildings, facilities, and infrastructure.
6. The military needs to develop the ability to use alternate water supplies. Opportunities to eliminate water consumption need to be evaluated.
7. The ability is needed to adapt to a water crisis in quality and quantity. Crisis conditions management includes contingency planning, use of alternate sources, emergency supply, critical infrastructure, and identification of problems among the drivers.
8. Technologies and techniques need to be developed to inactivate pathogens quickly and effectively. Also, the ability to quickly and cheaply identify the suitability of water for its intended use is needed.

The results of this workshop will be used to generate research and demonstration topics for future work in the area of water technologies to support sustainable installations and forward bases. In addition, it is expected that the results of this workshop will support the funding of research and project demonstrations. Possibilities for support are expected to be numerous, including the programs directed by the Army Research Office, the Strategic Environmental Research and Development Program (SERDP), the Environmental Security Technology Certification Program (ESTCP), and demonstration funds controlled by military entities with a focus on technology transfer in addition to partnering with universities, consultants, and other entities with national research efforts led by organizations such the National Science Foundation, the American Water Works Association Research Foundation, WateReuse, and other Federal organizations and National laboratories such as the Bureau of Reclamation and Sandia National Laboratory.

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Preface

The Military Applications for Emerging Water Use Technologies Workshop was jointly organized by the Construction Engineering Research Laboratory (CERL), Strategic Environmental Research and Development Program (SERDP), the Environmental Security Technology Certification Program (ESTCP), Army Research Office (ARO), University of Illinois, Army Environmental Policy Institute (AEPI), and Headquarters, U.S. Army Corps of Engineers (HQUSACE) as an initiative conducted for the benefit of Army and Department of Defense (DOD) installations and policy leaders. This Technical report documents the proceedings of that workshop.

The CERL Principal Investigators (PIs) were Richard J. Scholze, Gary L. Gerdes, and William D. Goran. PIs from other organizations were: Dr. Kurt Preston (ARO), Dr. John Hall (SERDP/ESTCP), Malcolm McLeod (HQUSACE), David Sheets (AEPI), and Dr. Richard Sustich (University of Illinois). The authors would like to acknowledge the contributions of the University of Illinois for hosting the workshop.

Thanks to Kay McGuire, Harold Balbach and Annette Stumpf for facilitating the breakout sessions for discussion. The authors also acknowledge and appreciate the contributions of all presenters and other participants at the workshop. A special thanks is extended to General Jeffrey Talley for providing a real-time highlight video presentation from Baghdad, Iraq. Thanks is also expressed to Marcelo Garcia for arranging a tour of University of Illinois Laboratory facilities.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary E. Johnston, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

For the military, water is a limited strategic resource that can impact whether an installation can expand or perform its assigned or additional missions and maintain quality of life. Nearly all surface waters have been allocated for use, making it difficult to get increased allotments. Groundwater extraction occurs faster than recharge. Droughts and water restrictions, once limited to arid and semi-arid regions of the country, have become more widespread. Water contamination or degradation occurs in or threatens many areas, increasing concerns for the natural environment and its maintenance. Communities surrounding, upstream, and downstream from military installations tend to expand and limit the amount of water available for installations. Such scarcities and conditions have caused costs for both water and wastewater treatment to steadily escalate. In fact, demands for water within forward operating facilities and theater environments are so high that the value of water may exceed that of fuel. Such extreme conditions highlight the need for water reuse, conservation, and new supply technologies.

Department of Defense (DOD) installations and forward facilities have stated goals, policies, strategies, and requirements regarding water and the environment that promote reductions in water consumption, e.g., Executive Orders mandating reductions in water use; Energy Policy Acts; installations' individual sustainability plans; requirements for Low Impact Development and LEED Silver certification. To ensure sustainable water use, and wise stewardship of valuable natural resources, the U.S. military is looking to enhance water access, conservation, and reuse with the proactive implementation of emerging technologies. This workshop is intended to help identify emerging science and technology solutions, as well as necessary basic and applied science, testing, and demonstration investments that will bring emerging solutions into military operations for forward, mobile, and fixed facilities.

Objectives

The objectives of this workshop were to share information, spread visibility of current efforts, and explore potential areas for existing, emerging, and future technologies and other options for water for DOD installations

and to potentially identify future research and demonstrations in the area of water technologies.

Approach

Richard Scholze and Gary Gerdes of the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) authored read-ahead documents to workshop participants focusing on (respectively) fixed facilities (Appendix B) and forward operations (Appendix C). Richard Sustich of the University of Illinois provided a read-ahead document, which included extensive background information and material, and which is available through URL: https://casi.erdc.usace.army.mil/focusareas/water/

The workshop was held at the Holiday Inn Hotel and Conference Center, Urbana, IL and University of Illinois WaterCAMPWS in Urbana, IL over a 3-day period. Appendix D includes the workshop agenda, hyperlinked to Presentation files, which are available to DOD members with Common Access Card access (https://casi.erdc.usace.army.mil/focusareas/water/). (Click on the "Military Applications for Emerging Water Use Tech" dropdown list.

Fifty-eight attendees participated, from the Army, Navy, and Air Force, other Federal and Government agencies, trade groups, universities, and the private sector. Appendix E includes a complete list of attendees.

Subject matter experts, government stakeholders, and representatives from other government, trade association, and academic interests made presentations. A number of facilitated breakout sessions were scheduled during the 3-day period to develop research needs.

Scope

This workshop was jointly organized by CERL, the Army Research Office (ARO), the Strategic Environmental Research and Development Program (SERDP), the Environmental Security Technology Certification Program (ESTCP), the Army Environmental Policy Institute (AEPI), Headquarters, U.S. Army Corps of Engineers (HQUSACE), and the University of Illinois and was limited to government stakeholders and invited academic and industry associations with interests in the water technologies area.

Mode of technology transfer

This report will be made accessible through the World Wide Web (WWW) at URLs:

https://casi.erdc.usace.army.mil

http://www.cecer.army.mil

2 Presentation Summaries

Emerging issues in the global water arena

Mark Shannon, Director of the Center of Advanced Materials for the Purification of Water with Systems (CAMPWS), presented an overview of world and U.S. water resources and consumption. Dr. Shannon addressed current issues in the global arena, and described how efforts addressing those issues should be focused. Dr. Shannon also briefly discussed a few of the research efforts within CAMPWS. Those efforts were presented in greater detail in his second presentation. The following sections elaborate on some of the points discussed at the Workshop that may be of specific interest to the military.

Global problem trends

- Growth of deserts means more land with scarce water.
- Transfer of population to urban areas uses up local water resources.
- Groundwater aquifers are becoming unsustainable due to over-pumping.
- Cross-contamination of surface waters and aquifers is growing.
- Major river systems have shortages during dry months.

Suggested general approach

- Move away from chemical oxidants and reductants to self-generated chemicals for treatment; recover resources from wastewater (nutrients, ammonia, methane, etc.).
- Move to zero discharge of waste and residuals.
- Use more sunlight, recover energy from wastewater.
- Develop bio-based detection of contaminants and pathogens.
- Develop point-of-use treatment systems that are simple and robust.
- Generally develop technologies that use less energy and chemicals, and do not need highly trained workers to operate effectively.

Examples of current research

- New methods are being developed to decrease energy and chemical requirements of desalination.

- Low-cost absorbable glass is being developed to remove petroleum products from water.
- Treated sand and sunlight are being used to remove organic compounds.
- Alternative disinfection methods involving pathogen traps, catalysts, and photocatalysts.

Summary of white paper presentation — Challenges and water technology objectives at fixed facilities

Bill Eng, Headquarters, Assistant Chief of Staff for Installation Management (HQACSIM) addressed the competition for water resources, water, and wastewater treatment and reuse options, and opportunities for research and development. Mr. Eng's presentation summarized the information found in the white paper with the same title, which is included in this report as Appendix B.

Summary of white paper presentation — Challenges and water technology objectives at forward operations

Kurt Kinnevan, U.S. Army Engineer School, Fort Leonard Wood, MO (now of ERDC-CERL) presented information on the cost of bulk water in the Iraq Theatre, water requirements per soldier/civilian contractor and for a company/battalion/brigade, criteria for successful water technologies at forward facilities, and an approach to improving water management in-theatre. Mr. Kinnevan added his on-site experience to the white paper with the same name included in this report as Appendix C.

Water technology research with military applications at Sandia National Laboratories

Mike Hightower, Sandia National Laboratories, Albuquerque, NM, focused on military-related research and technology development thrusts in the water and wastewater treatment areas. Information was presented about projects on the use of non-traditional water resources, advanced membrane research and development, brackish ground water desalination research and demonstration, and improved wastewater treatment approaches to improve reuse opportunities. Other research and development (R&D) thrusts discussed were reducing energy and water interdependencies including military applications and development of decision-support tools to support energy and water system surety in developing countries.

Water technology research at Water Research Foundation*

Chris Rayburn, Director of Research Management at AwwaRF, presented an overview of the AwwaRF program. AwwaRF is the research arm of the American Water Works Association, an association of drinking water utilities. In 2007, AwwaRF sponsored research projects worth $21 million, about half of which involved developing technology-based solutions to water utility problems and issues. Mr. Rayburn focused his presentation on two areas: alternative water supply, and emerging treatment technologies. Examples of specific projects funded by AwwaRF that may be of interest to the military are:

- Phytoplankton fouling of pretreatment and reverse osmosis membranes in seawater desalination.
- Novel hybrid forward osmosis process for impaired water and saline water sources.
- Comparing nanofiltration and reverse osmosis for treating recycled water.
- Zero liquid discharge for inland desalination.
- Desalination product water recovery and concentrate volume minimization.
- Assessing energy use and optimization potential of advanced water and wastewater treatment systems.
- Desalination facility design and operation for maximum energy efficiency.
- Evaluating carbon nanotubes as adsorbents for removing synthetic organic compounds.
- Can fuel cells provide safe and cost-effective potable water sources?

Water technology research at WaterCAMPWS

The second presentation by Dr. Mark Shannon focused on the goals and efforts of the Center of Advanced Materials for the Purification of Water with Systems (CAMPWS), an organization of universities, National laboratories, private corporations, and government agencies. Most of the research being conducted within CAMPWS involves improving current membrane treatment technologies and creating more effective and efficient membrane removal of contaminants.

* Formerly known as the American Water Works Association (AWWA).

DARPA MANTRA Program

Dr. Kurt Preston, Army Research Office, presented for Dr. Cindy Daniell, Program Manager, Defense Sciences Office. Dr. Preston presented general information on the Defense Advanced Research Agency (DARPA) and the Materials with Novel Transport Properties (MANTRA) program. Also discussed were new technologies that will lead to non-clogging, non-fouling particle separators and for removing dissolved salts and contaminants.

Keynote presentation by BG Jeff Talley — Water resources in Baghdad, Iraq

BG Jeff Talley presented an overview of water supply and treatment in the city of Baghdad. He discussed regional and local water resources, raw water distribution and treatment facilities, irrigation, and wastewater treatment. BG Talley discussed several specific terrorist actions involving water systems and related Engineer projects. He discussed water supply, provided by KBR contract, at Victory Base Complex, and concluded by discussing improvements needed to make the Iraqi water system more sustainable.

Navy water production and treatment needs

Dr. Paul Armistead of the Office of Naval Research presented an overview of the Navy research structure, current Navy programs and opportunities, and Navy shipboard needs. Dr. Armistead also described some of the challenges facing the Navy in providing water at sea vs. on land operations. The Navy research program is focused on developing a shipboard desalination system that is smaller, lighter, uses less energy, and is less expensive to own and operate than systems currently being used. The current generation of that equipment is the Expeditionary Unit Water Purification system (EUWP), which is in full scale demonstration. Ongoing research efforts include developing the following:

- 30-year ceramic micro-filtration (MF) membranes.
- Chlorine resistant reverse osmosis (RO) membranes.
- Light, quiet, low pressure membrane distillation.
- Lower pressure forward osmosis using magnetic draw solute.
- Forward osmosis membranes with higher fluxes.
- Reliable 90 percent energy recovery using hybrid recovery device.
- Electrocoagulation for MF/RO pretreatment.
- Increased flux RO membranes.

Electrocoagulation pretreatment for ultrafiltration

MAJ Thomas C. Timmes, Medical Service Corps and researcher at Pennsylvania State University, discussed the potential of electrocoagulation technology as pretreatment for ultrafiltration (UF) and pilot scale tests at Naval Facilities Engineering Service Center Seawater Desalination Test Facility in Port Hueneme, CA. He concluded that electrocoagulation for pretreatment was feasible, but not yet practical for field operations.

U.S. Army TARDEC

Dr. Jay Dusenbury, Deputy for Science and Technology at U.S. Army Tank Automotive Research, Development & Engineering Center (TARDEC) — RDECOM, presented an overview of TARDEC's involvement in providing deployable water treatment and supply technologies for the military. Dr. Dusenbury discussed new and existing equipment developed at TARDEC, equipment under development, and technologies being investigated. The current inventory of deployable treatment equipment primarily consists of 600 gph and 3000 gph Reverse Osmosis Water Purification Units (ROWPUs). The next generation of equipment, now in production, includes the 1200 gph Tactical Water Purification System (TWPS), the 75 gph Light Weight Purifier (LWP), and the CAMEL, an 850 gal water trailer with heating and chilling capability. Soon to be in production is the Expeditionary Water Packaging System (EWPS) to be used for filling plastic water bottles in conjunction with water purification equipment. Ongoing research efforts include:

- Testing new RO membranes for removal of chemical agents.
- Development of the Gator, a unit-level water purification and storage system.
- Development of water from exhaust and water from air systems.
- Development of sensors for instant water quality monitoring.

3 Key Points from Break-Out Group Discussion — Forward Facilities

The general topic of water supply and treatment at forward facilities was discussed during the Friday breakout session. The workshop was divided into three groups that discussed issues independently of each other. Each group was led by a facilitator who had been given a general outline around which discussion could be structured. Discussion was to progress through the following stages:

1. Identifying issues.
2. Defining constraints and parameters of each issue.
3. Current successful and unsuccessful efforts/technologies related to each issue.
4. Effectiveness of management to address the issues.
5. Listing specific technology gaps, and possible ways to mitigate those gaps.

The points made by members of the discussion groups were recorded by the facilitator in bullet format on an easel, and by one person in each group previously designated as scribe. Because of the breadth of the subject and time constraints, discussion evolved to being more unstructured and free-flowing. However, important points were made, though they could not be fleshed out in as much detail as was hoped. The following sections include a consolidated and generally unconstrained list of the key points made during all three breakout groups.

Issues

- Alternative sources of water are not being used or used effectively. Those noted were: rainfall, engine exhaust condensate, treatment effluent, solar distillation, portable desalination of salt and brackish sources, and cascade reuse. Use of alternative sources needs to be integrated into base camp planning and design.
- Soldiers do not like to drink bulk water; they find the taste, odor, and temperature objectionable in bulk water. The high temperature of the source water and the lack of de-chlorination contribute to the poor taste.
- Water treatment operations involving ROWPUs can be improved.
- A proponent to take ownership of base camps is needed. That proponent would coordinate base camp design and operations, and would

coordinate the development and fielding of new technologies. The proponent would establish base camp standards for water regarding treatment, usage, distribution, wastewater treatment, etc.

- Capability to quickly evaluate water sources to determine how they may be used or need to be treated.
- The "Force Provider" is not the answer for large operations due to limited assets. Need capability beyond the Force Provider scale as temporary camps evolve toward permanency.
- A base camp technology demonstration site is needed, for both water and energy technologies.

Constraints and design parameters

- The break-out group(s) defined the three stages of base camps as:
  - Initial or expeditionary (0 to 2 months). (Prior to this workshop, the initial stage was defined as 0-6 months.) In this time-frame, camp operations are less organized. The Army is on the move. Units carry 72 hours of supplies, after which re-supply (fuel, food, water, etc.) is needed. Treatment systems must be self-contained.
  - Temporary (2 months to 5 years). Initial systems may or may not be upgraded. This transition may not be handled well from an engineering perspective. There are challenges with scalability and maintaining efficiency due to constant changes in camp population. Systems are needed to handle a wide range of usage and power fluctuations.
  - Permanent or enduring (longer than 5 years).
- Minimum deployable unit (company, 150 men). It is unlikely to go below 150 person unit. A decentralized approach should scale up from there.
- Water technologies must be appropriate for the forward environment. Low-level technologies may be the most adaptable.
- Stage 2 base camps have "modular" waste streams. Modularity is a tradeoff with system efficiency.
- There is often no central collection and treatment until well into the Temporary stage.

Successful base camp efforts

- Force Provider concept (500 soldiers). This is not a base camp. There are 38 such sets in the Army, which are categorized as strategic assets. This concept has limited numbers of soldiers to support, can be scaled

down (researchers are looking at scaling down to ¼ size), but may not be scaled up.
- Life straws (LifeStraw™).
- DARPA backpack.
- Small portable desalinators (up to 4000 gal).
- Dust treatment.
- Army health is developing the Army Sentinel program, which focuses on specific toxins/contaminants.
- Laundry recycle and shower water quality standards — Dick Burrows, point of contact (POC) from the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM).
- Designed water treatment plant for large numbers.
- Air Force has:
    - Base camp modules to take care of 55.
    - Basic Expeditionary Airfield Resources (BEAR) and modules for up to 1000 people.
    - Red Horse team.
    - Well drilling team as part of the Rapid Engineer Deployable Heavy Operational Repair Squadron (RED HORSE).

Management gaps and recommendations

- Base camp command is assigned to an officer of appropriate rank and availability. These officers may not have the correct training for "running facility resources," but they may get the assignment.
- Engineer experience on the ground (needed).
- Systems approach — modular.
- Demand reduction.
    - Emphasize reuse.
    - Evaluate/develop reuse policy and usage standards.
    - Educate soldiers to adjust attitude toward reuse.
- Need to be in concert with locals (not in competition) when using local resources.
- Determine whether stability operations and combat operations require the same water resource capabilities/equipment.

Technology gaps and recommendations

- Evaluate alternative water sources to minimize re-supply requirement.
    - Local ground and surface water.
    - Brackish and sea water.
    - Precipitation (stormwater).

- o Water vapor.
  - * Water vapor in air.
  - * Condensate from fuel combustion (generators, heaters, etc).
  - * Fuel cells.
  - * Laundry dryers.
- o Solar distillation.
- o Desalination.
  - * Should be portable.
  - * Evaluate alternative energy sources.
- o Reuse wastewater treatment effluent.
  - * From treatment lagoons.
  - * Dewater sludge, sediment.
  - * For dust control.

- Develop/validate/implement water conservation wherever possible.
  - o Waterless toilet and urinals.
  - o E-loo — evaporating toilets.
  - o Waterless bathing and food prep.
    - * Limit showering.
  - o Eliminate blackwater.
    - * Compost food waste and/or fecal material.
  - o Closed loop laundry, including capturing water from drying cloths.
- Capture energy from wastewater.
  - o Reuse power for processes.
  - o Recovery energy from dining facility food waste.
- Use water bottles for energy source.
- Generate energy from water production/activities. (How can this be done?)
- Improve water logistics and security requirements.
  - o Implement mobile bottling and packaging capabilities (currently looking at commercial off-the-shelf [COTS] capabilities).
  - o Encourage hydration pack, individual, and bulk capability.
- Improve the taste of water.
  - o Develop disinfection alternatives to improve taste.
  - o Disinfection at point of use.
  - o Water chilling capability - Camel has problems.
  - o Remineralization of RO water to improve taste, reduce corrosiveness.
- Develop treatment equipment that is expandable/modular, able to accept variable influents.
- Treat to standards for its intended use (nonpotable).
  - o Develop standards where needed.

    - Only shower (gray) water needs to be treated to drinking water standards.
- Develop technology to treat/recycle source-specific wastewater.
    - Focus on: latrine, kitchen, laundry, shower.
    - Soapy water collection and treatment — kitchen, laundry, showers/sinks.
    - Isolate blackwater components — solids/liquids, kitchen waste, urine/feces.
- Identify cascade water use/reuse opportunities to minimize treatment.
- Investigate alternative treatment technologies.
    - Develop rapid start-up bioreactors.
    - Membrane bioreactor.
    - Evaluate sulfur removal with CuO/Al_2O_3.
- Develop wastewater treatment package plant.
- Develop stormwater treatment system.
- Improve current membrane treatment processes/ROWPU.
    - Make potable treatment flexible to enable bypass of pumps/filters.
    - Add capabilities that result in less frequent change-out of RO filters.
    - Develop sensors to determine when membrane bypass is appropriate.
    - Develop advanced membranes.
    - Concentrate brine waste.
    - Add a pretreatment capability to remove silicates from groundwater.
- Improve ability to test/monitor as needed.
    - Develop/demonstrate "lab on a chip" technologies.
    - Monitoring equipment to enable treatment barrier reduction, match treatment barrier to source.
    - Develop capability to detect toxins in water supply.
    - biological oxygen demand (BOD) sensors needed.
    - No online viral detection schemes exist.

4 Breakout Group Discussion for Sustainable Fixed Facilities

Originally, two sessions were dedicated to fixed facilities, but there was substantial overlap in the content recovered from the sessions. Due to a time shortage in the workshop, the information was consolidated into one chapter focused on sustainable fixed facilities.

The workshop was divided into three groups that discussed issues independently of each other. Each group was led by a facilitator who had been given a general outline around which discussion could be structured. Discussion was to progress through the following stages:

1. Identifying issues.
2. Defining constraints and parameters of each issue.
3. Current successful and unsuccessful efforts/technologies related to each issue.
4. Effectiveness of management to address the issues.
5. Listing specific technology gaps, and possible ways to mitigate those gaps.

The points made by members of the discussion groups were recorded by the facilitator in bullet format on an easel, and by one person in each group previously designated as "scribe."

Because of the breadth of the subject and time constraints, discussion evolved to being more unstructured and free-flowing. However, important points were made, though they could not be fleshed out in as much detail as was hoped. The following sections consolidate a generally unconstrained list of the key points made during all three breakout groups.

The general goal of the session was to outline the technology development needed to maintain sustainable fixed facilities over the short term. The white papers were a starting point, complemented by the various presentations and attendees' background knowledge. The sessions aimed to:

- Identify developing technologies with a potential for enhancing water supply from traditional and alternative sources.
- Identify other technologies currently being demonstrated or fielded that can enhance water supply from traditional and alternative sources and other off-the-shelf technologies with potential for applications.

- Identify additional water conservation technologies with potential application at fixed facilities.
- Identify future opportunities.

The results of the free-flowing discussion were organized as follows:

- "*Introductory material*" discussion set the stage.
- "*Background issues*" listed some of the topics mentioned that impact military operations.
- "*Current feasible applications and opportunities*" identified some of the ways water could be more efficiently used on installations, including water reuse and other sources of supply, e.g., off-site supplies, wastewater, and harvested rainwater.
- "*Constraints*" discussion mentioned were impediments to changes that would introduce or improve water management.
- "*Challenges*" section expanded on that approach.
- "*Other technologies that could be used at DOD installations and future opportunities*" introduced some ideas not widely applied to military installations.
- "*Future opportunities*" presents a list of potential research thrusts.

Introductory material

An installation or base needs a balance of potable and non-potable water, and a balance of investment, resources, and manpower to meet mission requirements. We have command emphasis to make changes occur that might otherwise be resisted, to:

- Educate installation occupants regarding water saving attitude.
- Determine the minimum water needs by function, and by quality required.
- Determine what can be done in new construction.
- Absence of regulatory guidance for reuse.
- Needs:
    - Army doctrine and guidance is essential to establish mechanism in specs, etc to incorporate new ideas.
    - Buy-in from Construction/value engineers.
    - Better master planning.
    - Holistic approach for infrastructure — in particular water/energy.
- The concept of a "water footprint" was introduced. This is a method or measure to show the impact of an entity's use of water.
- Risk assessment for nonpotable.
- Pathogen control important for use.

- More regional coordination, i.e., "we are not in a vacuum."
- Education/training and awareness are essential to promote water reuse/conservation and new technologies.
- The concept of a Technology Demonstration Platform "Fort Water Conservation" was promulgated (to identify a particular base that can verify technologies).
- Demonstration of more existing technologies is needed that would validate ideas and technologies and provide technical information to show what works.
- De-centralized efforts (allow installations to use initiative).

Background issues

Where is water used on an installation?

- Water audit capability. Should there be a policy?
- A facility audit on an installation (of where water is used) should be done to track every drop used. Major categories include: irrigation, domestic, industrial, mission, recreational, and environmental.
- The principles of Total Water Management: a holistic approach incorporating stormwater/wastewater/precipitation and traditional/non-traditional, brackish, conservation are one way of producing a complete water budget on an installation.
- Most military installations do not know where and for what purpose water is being used, a complete inventory on institutions and facilities that use water, including consumptive uses is needed. The most accurate way to achieve this is through metering. An inventory of consumptive uses should be developed.
- Water conservation in each facility. (What do you use water for?)
- Meters to be read and problems in reading existing meters are often low priority issues.
- Education — Officer Record Brief (ORB) to show occupant water/energy use.
- How to do self-assessments.
- Idea: Create an assessment team for water uses to evaluate the installation, measure water consumption at various activities, establish a baseline, and identify opportunities for improvement.

Lack of a common language for water

Definitions are not commonly understood by members of the user community: utilities, medical, facilities, environmental, etc. Standards and cri-

teria may need to be developed for various types of water for non-potable applications. The current guidance is state specific and general. Terms such as blackwater, graywater, safe, non-pathogenic, nonpotable, and others need a common point of reference.

System size and capacity concerns

Military installation water systems are sized generally by fire suppression needs. Unified Facilities Criteria (UFC) provide line sizes guidance e.g., hangars need certain sizes. It would be possible to use small diameter pipe for potable needs and larger diameter for fire and nonpotable uses with appropriate considerations and cross connection control. Forward deployed units can use smaller systems.

Personal use

Previous policy regarding water has been based on entitlement, with no constraints placed on quantities used. However, when users pay for water, consumption drops. For example, at Fort McClellan, when the policy was changed to require users to pay for usage, bills went down. This suggests that there is a benefit associated with a shift to personal responsibility. Military installations could establish a baseline for water use in housing, beyond which residents would pay for "extra" consumption. Another example where people in the services were asked to participate in helping to reduce water use is West Point, which established a "post average"; users who consume more than the average, pay; users who consume less than the average, get a rebate.

- Metering in housing coming, will have policy incentives.
- Randolph Air Force Base (AFB) is completely metered, and meters are read remote.
- Clarify individual water consumption and responsibility.
- Water conservation in Air Force has been top down, people have not been asked to participate.
- Establish a regulation/law or it will not be done. To encourage water reuse, some driver is required.
- Security in distribution system requires water system vulnerability assessments. An impact of privatization is the need to negotiate with utility. For example, Fort Drum's Supervisory Control And Data Acquisition (SCADA) system for water uses enhanced monitoring and detection systems and access control.

Current feasible applications/opportunities

- Management strategies.
  - Directives/Policy /Doctrine.
  - Regulatory drivers.
  - Residential programs — meters, education, awareness.
- Many management strategies are well developed; they just need to be fully implemented.
- May need to show restraint (or go slow) on implementing new alternative or extreme technologies and focus on the practical solutions at hand: leak detection surveys (find and fix), irrigate with nonpotable water, rainwater harvesting, stormwater detention, waterless urinals, etc.
- Many short-term options are not tied to technology.
- Rainwater harvesting, rainwater — maximum use — includes: cisterns and stormwater runoff from larger surfaces, runoff to reservoir — then process for use?
  - Airfields collect runoff — then use for fire protection.
  - Recharge groundwater with runoff.
  - Better water treatment for rainwater/stormwater.
- Graywater Use.
  - Graywater systems in Air Force need review by bioenvironmental engineer.
  - Subsurface irrigation uses graywater.
- Purchasing of water rights.
- Wastewater effluent reuse.
  - For example, Orange County — treat wastewater, inject, pull out later, avoids saltwater intrusion.
  - For example, golf course irrigation, cooling water, boiler makeup.
- Direct reuse of wastewater effluent to augment potable supply.
- Point of use recycle not being used.
- Additional water conservation measures:
  - Automatic water faucets.
  - Waterless urinals.
  - Short term technology needs are for reuse.
  - Dual flush toilets.
- Leakage control.
  - Technologies are available to add metering in cost effective way.
  - Will they provide metering in privatized housing (going to automatic meter-reading system)?
- Cooling towers can yield 10 to 20 percent savings per tower in blowdown water. Cooling tower technologies decrease blowdown water, and

encourage more recycles. Although there have been problems with many cooling tower technologies in past, CERL involvement can help with evaluations, recommendations, or similar third party verification to better enable these technologies to be used.

- Landscape issues.
- Irrigation management plan.
  - Sensors.
  - System shuts when not needed.
- Zeroscaping and xeriscaping.
- Smart irrigation technology.
  - Drip irrigation.
  - Sub-surface irrigation.
- Turf grass — what is appropriate mix.
- Artificial turf on golf courses?
- Golf courses (design to collect stormwater and reuse water).
- Installation design standards. (Change plant standards/policy to reduce water consumption.)
- Green roofs.
- Ranges can use nonpotable water for construction.
- Public education.

Constraints

- Rainwater harvesting may be limited by states water rights.
- Western states must comply with state water rights laws.
- Accountability.
- Wastewater plants are being privatized; recycle of effluent not an easy option.

Challenges

- Making technology work — then making technology work in specific installation application.
- What is the water need/budget for installations and surrounding regions.
- Should we add meters for power, water, and wastewater.
- States with water rights — is it even more important to reuse?
- Maintaining water rights.
- Water rights issues needs policy to avoid adjudication and loss.
- Future scenarios on water availability, e.g., to respond to a scarcity problem, show leaders the issue so we can get new water policies for reuse and reclaimed water, etc.

- Color of money for retrofit of fixtures vs. irrigation vs. implementing new technology.
- Geography of available sources.
- Look at systems approach (Rio Grande); monitor where water is going.
- Conflicting pressures — city/region has to work with installation.
    - Be involved with local government planning bodies.
    - Regional issues — base/community.
- Energy Conservation Investment Program (ECIP) for Military Construction (MILCON) dollars for energy and water saving retrofits. (Change criteria for cost of water so these projects payback sooner.)
- LEED Silver, but how to incorporate reuse of water into our projects (MILCON$).
- Need the Sustainable Project Rating Tool (SPiRiT) for Army family housing and Residential Communities Initiatives (RCIs) — LEED homes, where installations are currently not building in water management systems.
- Policy gap — LEED for neighborhood development, LEED for base-wide.
- Mixed use — how to mix facility types/plan cascading reuse.
- Goal — ZERO DISCHARGE.
- Area development plan — address stormwater, stormwater is often a resource that can be put to beneficial use instead of being moved off-site as quickly as possible.
- Policy recommendation — need policy in place to make investments make sense.
    - Reduce non-potable use of potable water.
    - Water needs — investment — mission risk.
    - Water and energy are inextricably linked.
- LID guidelines — regional BMPs.
    - Partner with DOD, U.S. Environmental Protection Agency (USEPA).
    - Homes, neighbors, existing buildings, ranges.
- 1391 process utilities get short shrift for upgrade.
- Compartmentalization of funding.
- LID documentation needed to show cost-effectiveness, help to get buy-in from decisionmakers and program and project managers, construction division.
- Self-help program for RCI (Residential Communities Initiative) similar to what had been available for on-post family housing where troops could get and install on their own: low flow showers, sprinklers, etc.

- Water Sense, Energy Star reviews and approvals of products that use less water.
- Equipment.
- Design package for Headquarters (HQ).
- How to get water efficiency-reuse, into design-build projects.
- Need a way to get generically into system so construction people can use, i.e., Rainwater Harvesting.
- How to get water reuse into specifications.

Other technologies that could be used at DOD installations

- Riverbank infiltration — wells along river.
- Natural or artificial wetlands.
- Alternative source of water.
- Oceanside, reverse osmosis treatment and desalination have operational advantages.
- Sink to toilet systems.
- Membrane bioreactors.
- Desalination of groundwater.
- Eliminate evaporative cooling.
- Reuse laundry, shower water.

Future opportunities

- Security and distribution.
  - Enhanced monitoring.
  - Decentralized approaches.
  - Data to central location.
- Capturing water from exhaust and from air (combustion).
  - Capturing water from air (other methods).
  - No-flow toilets.
- Fuel cell technology.
- Energy efficient washracks.
  - Recycling systems.
  - Aircraft.
  - Heavy equipment.
  - Civilian/privately owned vehicle (POV).
- Solar for pathogen inactivation using fluorescent lighting.
- Military handheld test protocol for CHPPM.
- Enhanced membrane technology.
- Point of entry disinfection.
- Dual pipe systems - potable and nonpotable.

    - Separate water supply for drinking, showering, washing, etc.
    - Separate fire suppression (Examples: Johnson atoll, sweet water and saline, two lines).
- Kwajalein also robust system dual systems.
- Fort Irwin dual system, potential health concerns.
- Aurora, CO dual system, others scattered around, Greenbuild, SC as an example town.
- Existing water distribution system to purple.
- New potable water (office, cooking, housing).
- In-house Reverse osmosis?
- Local filtering for potable water (maintenance headache).
- Point of use — maintain potable in housing, but change other? (Need a simple, easy to understand system.)
- Need management scheme to reduce water use in a crisis (like we have for power) when sanitation becomes critical.
- Policy — reduce use of potable water for non-potable use.
- Define what a water management plan is.
- LID (Low Impact Development) Tech DemVal.
- Best management practices for stormwater.
- Stormwater management BMPs.
    - Application (region, climate, soil type) at area scale.
    - Quantification of effectiveness.
    - Database of ready to go LID BMPs by region.
- Sustainability/operational cost/benefit analysis needed.
- Asset management construct (air force) to articulate risk to mission dependency index of not supporting infrastructure/backlog of maintenance and repair (BMAR) and requirements.
- Membrane bio-reactors in limited space for point of use treatment.
    - Anaerobic — research ready to be tested pilot scale.
    - Can be centralized or decentralized.
    - Work better for concentrated waste streams.
- Energy/volume capability for treatment tech.
- Methane bioreactors — natural gas/electricity.
    - Closed systems.
    - Make money for energy at our plant size?
    - Ammonia — lot of energy to prod for ag — can it be harvested?
    - Small scale anaerobic — fuel to cook, compost, liquid.
- Brine waste — testing and treatment.
- Water meters — sensors — monitored via the internet.
- Better sensor technology for real time/remote sensing/monitoring.
- Service life of sensors is very important.

- Electro coagulation. Use positive and negative currents passing through two parallel plates.
- Electrodialysis, which Uses + and — currents passing through a membrane.
- Ultrafiltration followed by reverse osmosis.
- SMART molecules.
- Fixed film bioreactors.
- Nanotubes: where do they fit into the grand scheme of things?
    - Cost.
    - What do they replace.
    - Nanotube implications — nanoparticle hazard.
    - Ozone backwash for nanotube (micro?).
    - Many treatment applications — reuse, desalination, etc.
- Ceramic membranes.
- Energy recovery from wastewater.
- Vapor recovery from JP8 combustion.
    - Problem with high sulfur in vapor.
    - 72 percent of all DOD energy consumed is jet fuel (52 percent U.S. Air Force [USAF] jet fuel).
- Forward osmosis.
    - Pure desalination.
    - Pre-treatment for reverse osmosis.
- Distributed treatment — point of use treatment.
    - Both for raw water.
    - Wastewater (graywater, blackwater).
- Biomimicry (biomimetic processes or equipment).
- Integrated testing of advanced technologies.
- Innovative combinations of technologies.
- Water supply during emergency situations, i.e., create a contingency plan.
- Non chemical treatment of cooling towers.
- POE^2 (point of entry-point of exit) with direct reuse to/from a high quality non-potable.
- Combined rapid, remote microbial monitoring/pathogen concentration technique.
- Minimize facilities by highly distributed operations.
- Power reliability technologies.
- Localized recycle/reuse to reduce energy for pumping treated and wastewaters.
- Rapid water testing.
- Pathogen concentration techniques for monitoring.

- Housing and distribution/collection systems are being privatized. (This may end in 2010.)
- Perception that green landscaping is necessary.
- Water is too cheap.
- Full value of water not considered when evaluating water system repair projects.
- Office of the Assistant Chief of Staff for Installation Management (OACSIM) “System upgrades are not going to happen.”
- Installations may guarantee a certain amount of wastewater to a regional wastewater treatment plant.
- Funding constraints due to operations outside the continental United States (OCONUS).
- Reluctance to use wastewater effluent.
- Geography matters — water supplies and quality vary.
- Potential Policy issue — is there any military guidance related to graywater reuse, or only state regulatory requirements.
- Effluent reuse — no military guidance.
- Policy statement: Installations will develop a zero discharge fence to fence.
    - Stormwater.
    - Treated effluents.
    - Reclaimed water.
    - All water that comes on the installation, stays on the installation.
- Risk assessment work for nonpotable water reuse; is there human use, and if so, what is health risk potential?
- Point of use technology where human contact involved.
- Decreasing water availability because source estimates are based on a wet century could result in:
    - More water allocated than we should expect.
    - Decreased wastewater (WW) flow means more concentrated waste.

5 Summary, Conclusions, and Recommendations

Summary

The first Military Applications for Emerging Water Use Technologies workshop was held at the Holiday Inn in Urbana Illinois over a 3-day period in which subject matter experts and government stakeholders gave presentations, shared information, and participated in discussion groups to explore the future of water use technologies at DOD installations and to develop potential research and demonstration needs to further the implementation of water technologies. There was a focus on water access, conservation, and reuse.

The freewheeling discussions during the workshop provided a number of ideas along with constraints and background information necessary to support sustainable water use at military installations while raising the level of awareness of what is occurring in the research and application community outside of military installations. Concern over water supply is emerging as a major consideration in determining whether the DOD can actively pursue its missions to best advantage while shifting troops, equipment, and resources around the country with minimum impact on local regions competing for the same water supply.

Recommendations and next steps

The results of this workshop will be used to generate research and demonstration topics for future work in the area of water technologies to support sustainable installations and forward bases. In addition, it is expected that the results of this workshop will support the funding of research and project demonstrations. Possibilities for support are expected to be numerous, including the programs directed by the Army Research Office, SERDP, and ESTCP, and demonstration funds controlled by military entities with a focus on technology transfer in addition to partnering with universities, consultants, and other entities with national research efforts led by organizations such the National Science Foundation, the American Water Works Association Research Foundation, WateReuse, and other Federal organizations and National laboratories such as the Bureau of Reclamation and Sandia National Laboratory.

Conclusions from workshop (forward facilities)

1. Much of the discussion regarding forward facilities involving the issues, constraints, management, and technology needs validated the information contained in the white paper presented by Kurt Kinnevan (included in Appendix C to this report).
2. It was the group consensus that water management at forward facilities can be improved by:
   - Implementing treatment and reuse at point of use, and cascade reuse.
   - Implementing water conservation measures.
   - Using alternative and innovative water sources.
   - Implementing technologies that are expandable, making increases in camp size and transition to long-term operations more seamless.
   - Using a systems approach to base camp design and operation.
   - Using appropriately trained personnel for base camp design and operation.
   - Having an organization assume ownership of forward facilities.

3. There was discussion of specific needed technologies, of which the following are being addressed by RDECOM, the Office of Naval Research, Sandia National Labs, TARDEC, and Water CAMPWS:
   - Improving treatment provided by the existing ROWPU — all of the above mentioned organization are involved in research to improve membrane treatment and/or research to develop next generation deployable systems.
   - RDECOM is developing a "lab on a chip" for immediate analysis of water samples.

4. Other needed technologies were not specifically addressed by the presenters. These include:
   - Stormwater treatment system.
   - Rapid start-up bioreactors.
   - Separate treatment for wastewater solids.
   - Recover energy from wastewater and water bottles.
   - Many others listed in the Key Points chapter.

5. All three breakout groups noted that a base camp water technology demonstration site was needed.

Way forward — Forward facilities

The costs for the security and energy resources to transport water are staggering. More important is the risk of soldier casualties when transporting water across unsecured areas. The most important goal to improve the management of water at forward facilities is to reduce the amount of water being hauled by tanker trucks from a water source to a base camp. This must be accomplished by water reuse, water conservation, and the use of non-conventional water sources. The way forward must focus on these things.

Because there is a direct relationship between energy and water, the way forward must also focus on reducing the energy needed in water management. The water resource itself is usually inexpensive, if not free. But a significant amount of energy is necessary to treat raw water; transport and distribute the treated water to users; and cool the water for drinking. Wastewater treatment is also energy intensive. Clearly, to decrease the cost of water in theatre, the amount of energy needed to manage water must be decreased.

The way forward also must include improved management. Addressing the need to develop guidance and technologies for sustainable forward facilities is filled with opportunities, but lacking in direction. While a systematic approach is definitely needed to improve base camp operations, the Army has no mechanism to define that approach. Currently no command organization has been designated to take ownership of forward operations and to orchestrate the technological advancement of those operations. Clearly, the first step of the way forward is to establish that responsibility within the mission of an existing organization, or to create a new and dedicated organization for that purpose.

Fortunately, the Maneuver Support Center at Fort Leonard Wood is leading the way in establishing that organization. An Integrated Capabilities Development Team for forward facilities has been created, and has included in the goals the creation or naming of an organization that will control forward facility doctrine and technology development. The ICDT may also establish a location that will serve as a national test bed for the demonstration/validation of those technologies.

Following the creation of that organization, a true way forward for development and implementation of technologies can be defined. First operational and performance goals must be set. Then, based on impact of

achieving each goal, those goals should be prioritized. Finally, the path to each goal should be defined by identifying the efforts necessary to research, develop, and test the new technologies needed. The discussion points made and presentations given at this workshop are a good starting point. The way forward will include, but not necessarily be limited to, the following topics for developmental research and demonstration projects:

1. Innovative sources of water must be exploited. Possible efforts would include: developing efficient ways to condense water from air; developing efficient ways to condense and purify water from the exhaust of both mobile and stationary engines; developing designs of portable structures that incorporate features to harvest precipitation; and developing forward facility planning guidance that includes grading and piping to permit capture and storage of precipitation.
2. Water reuse technologies must be developed. Much work has been done, but resources are still needed to demonstrate newly developed, but unproven technologies, to continue the development of new and promising technologies, and to conduct basic research that will lead to new technology or make existing technology more practical. Prototype systems have been developed to recycle shower and laundry water at the point of use. But these systems rely on existing treatment technologies that are still in need of improvement. There is still a need for the development of innovative technologies for point-of-use reuse treatment, for wastewater generated by ablution/shower units, laundries, dining facilities, and vehicle washing.
3. Implementation of water conservation, i.e., eliminating waste, and reducing the water requirement for a specific use, has the same effect as reuse on decreasing demand. Off-the-shelf, low-flow devices have been implemented, e.g., low-flow shower heads and front loading clothes washers. However, there are opportunities for the development of innovative low-water or waterless technologies for washing laundry and equipment, for food preparation, and for bathing and personal hygiene, etc.
4. There is much on-going work to improve current water management technology by reducing energy demand. Specifically, much needed research is developing better membranes for raw water treatment and recycle treatment — membranes that are more resistant to fouling and are more efficient. Much work is yet to be done with regard to membrane treatment, including developing appropriate pre-treatment. Even as membrane treatment problems are being addressed, alternative treatment scenarios should also be considered, at both the basic and applied research levels.

Another opportunity to improve energy efficiency is to improve the efficiency of heat transfer when heating and cooling water. The waste heat from cooling drinking water can be captured for beneficial use. Alternative methods of cooling water can be developed that exploit renewable energy and perhaps geothermal heat sinks.

The resources to fund technologies with the above R&D topics are not unlimited. Therefore proposed efforts must eventually be prioritized. That ranking can be accomplished by evaluating how well the product of a proposed effort meets the following criteria/goals for any forward facility technology.

The equipment used for the sustainment of forward operations must be suitable for base camp application, and must meet the following criteria:

- *Deployable*. Equipment must be designed to be shipped in standard CONEX containers, quickly set up, and easily relocated. It must not require significant site preparation, and it must be adaptable to various climates.
- *Expandable*. Equipment and systems must be capable to grow with the camp, and must be compatible with large and sudden changes in the camp population.
- *Durable*. Equipment must be able to withstand abuse from shipping and soldier operation.
- *Simple*. As an Army asset, equipment must be able to be operated and maintained by minimally trained soldiers or host nation personnel.
- *Energy Efficient*. Equipment should not place a significant burden on the energy resources of the base camp.
- *Minimal Force Protection Demand*. Equipment that requires hazardous chemical or fuel storage, that depends on services procured from outside the base camp or that depends on the local population, equipment that is vulnerable or requires special protective measures, all create a burden on force protection resources. Since movement of non-Army service vehicles through the camp perimeter is a security risk, technologies that do not require constant replenishing of consumables or frequent on-site manipulation are preferred.
- *Minimal Environmental Impact*. Sanitation equipment and systems must be designed with consideration of the effect that air, water, and solid waste emissions may have on the health of the soldiers, and with consideration for the cleanup that will be necessary following redeployment of the base camp.

Conclusions — Fixed facilities

An installation needs a balance of potable and nonpotable water to meet mission requirements and a balance of investment/resources/manpower to meet its mission. With the military command structure, an appropriate emphasis can drive the forces of change and increase the speed of implementation. A primary difference between fixed and forward facilities is the cost to deliver product water, the dollars per gallon for forward facilities vs. dollars per kgal in fixed facilities (where efficiencies of scale exist).

One of the primary findings was a need to know where and how water is used on installations and the requisite quality. Tools and methodologies exist, but are not implemented.

There was an agreement that demonstrations of emerging technology and existing technology would be useful to show other installations both the feasibility and cost/benefit considerations for implementation at their locations. These could be concentrated at one location or spread around with appropriate technology transfer mechanisms. Representative topics include:

- stormwater and rainwater harvesting.
- leak control.
- graywater reuse.
- changes in irrigation through advanced technology.
- changes in plant selection and landscaping using xeriscaping and zeroscaping.
- advanced cooling tower treatment.
- aquifer storage and recharge.
- riverbank filtration.

Many existing technologies need to be demonstrated on military facilities. There needs to be a way to encourage adoption through the construction, design-build, and implementation stages of projects.

Use of stormwater as a resource where appropriate. Encourage tenets of Low Impact Development (LID) and LEED to support sustainability.

Numerous research topics and technologies were identified that will support fixed installations. The presentations and white papers identify many of them. Research is occurring throughout the United States and world

and it is essential to maintain awareness and to be able to adapt and adopt technologies to support water needs at fixed facilities.

Way forward — Fixed facilities

Water and energy are closely linked. Both should be use wisely. Distribution, processing, storage, and cooling of water requires energy, and energy savings are possible in all these processes. Many energy processes are also water intensive. Water use technologies are needed that reduce the energy demand, and energy and power technologies are needed that reduce the water demand. All energy and water technologies should be viewed in terms of their “balancing” of energy and water requirements. In addition, options such as recovering energy from waste water treatment processes need to be explored.

Water should be treated to match its intended use. The military often treat water to a higher standard than the resulting use, increasing treatment costs, energy demand, and missing opportunities for potential reuse. Water treatment and distribution technologies including point-of-use are needed that affordably provide options for water treatment to be closely matched to intended water use, while still protecting users from potential unsafe uses of water.

Engineering improvements are available now to improve water conservation, meet low-impact development requirements, and reduce input requirements in forward and fixed facilities. There are numerous capabilities that are already (or will soon be) available in the marketplace. The military needs to invest, through programs like the Army’s Technologies Standards Group ITTP program, and the OSD ESTC Program, to evaluate and demonstrate these capabilities for wider use in military operations. Investments in cost/benefit analysis, field testing, and demonstration and acquisition planning are necessary to achieve the benefits that can be provided to water distribution systems, irrigation systems, scalable water treatment and distribution, etc.

Water technologies and techniques should be explored that limit input of both water and energy, e.g., increased efficiency in operations and maintenance, reduction of amount of energy to produce a given amount of water, and improved materials (like membranes and carbon nanotubes).

Water “budgets” are needed to better understand current water uses and losses in both fixed and forward operations. The Army is undertaking a

"water budget analysis" for 10 installations, and this should provide valuable data to help focus technology investments and water infrastructure enhancements. Future infrastructure enhancements should provide for water reuse options, multiple water treatment/distribution networks, and the collection and reuse of rainwater and stormwater for buildings, facilities, and infrastructure.

The military needs to develop the ability to use alternate water supplies. An array of options is available: water reuse, sewer mining, graywater use, rainwater harvesting, and use of brackish groundwater. Technology is needed to use these alternate sources affordably and effectively. "Cascade opportunities" (reuse of water multiple times prior to disposal) can add to the beneficial use of water. Opportunities to eliminate water consumption need to be evaluated.

The ability is needed to adapt to a water crisis in quality and quantity. Crisis conditions management includes contingency planning, use of alternate sources, emergency supply, critical infrastructure, and identification of problems among the drivers.

Technologies and techniques need to be developed to inactivate pathogens quickly and effectively. Also, the ability to quickly and cheaply identify the suitability of water for its intended use is needed. This would require new methods for water quality testing.

Recommendations and next steps

The results of this workshop will be used to generate research and demonstration topics for future work in the area of water technologies to support sustainable installations and forward bases.

Unit Conversion Factors

Multiply	By	To Obtain
Acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
angstroms	0.1	nanometers
atmosphere (standard)	101.325	kilopascals
bars	100	kilopascals
British thermal units (International Table)	1,055.056	joules
centipoises	0.001	pascal seconds
centistokes	1.0 E-06	square meters per second
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
fathoms	1.8288	meters
feet	0.3048	meters
foot-pounds force	1.355818	joules
gallons (U.S. liquid)	3.785412 E-03	cubic meters
hectares	1.0 E+04	square meters
horsepower (550 foot-pounds force per second)	745.6999	watts
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
kilotons (nuclear equivalent of TNT)	4.184	terajoules
knots	0.5144444	meters per second
microinches	0.0254	micrometers
microns	1.0 E-06	meters
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
mils	0.0254	millimeters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters

Multiply	By	To Obtain
pints (U.S. liquid)	4.73176 E-04	cubic meters
pints (U.S. liquid)	0.473176	liters
pounds (force)	4.448222	newtons
pounds (force) per foot	14.59390	newtons per meter
pounds (force) per inch	175.1268	newtons per meter
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
quarts (U.S. liquid)	9.463529 E-04	cubic meters
Slugs	14.59390	kilograms
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (force) per square foot	95.76052	kilopascals
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (nuclear equivalent of TNT)	4.184 E+09	joules
tons (2,000 pounds, mass)	907.1847	Kilograms
tons (2,000 pounds, mass) per square foot	9,764.856	kilograms per square meter
Yards	0.9144	meters

Acronyms and Abbreviations

Term	Spellout
ACSIM	Assistant Chief of Staff for Installation Management
AEPI	Army Environmental Policy Institute
AFB	Air Force Base
AFCESA	Air Force Civil Engineer Support Agency
ARO	Army Research Office
AWWA	American Water Works Association
BG	Brigadier General
BMAR	backlog of maintenance and repair
BOD	biological oxygen demand
CERL	Construction Engineering Research Laboratory
CHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
COTS	commercial off-the-shelf
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
ECIP	Energy Conservation Investment Program
ERDC	Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
ESTCP	Environmental Security Technology Certification Program
EUWP	Expeditionary Unit Water Purification
EWPS	Expeditionary Water Packaging System
HQ	headquarters
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
LWP	Light Weight Purifiers
MF	micro-filtration
MILCON	Military Construction
NAVFAC	Naval Facilities Engineering Command
OACSIM	Office of the Assistant Chief of Staff for Installation Management
OCONUS	outside continental United States
ORB	Officer Record Brief
POC	point of contact
POV	privately owned vehicle
R&D	research and development
RCI	Residential Communities Initiative
RDECOM	Research, Development, and Engineering Command
RED HORSE	Rapid Engineer Deployable Heavy Operational Repair Squadron

Term	Spellout
RO	reverse osmosis
ROWPU	Reverse Osmosis Water Purification Unit
SBR	sequencing batch reactor
SCADA	Supervisory Control And Data Acquisition
SERDP	Strategic Environmental Research and Development Program
SERDP	Strategic Environmental Research and Development Program
SPIRIT	Sustainable Project Rating Tool
TARDEC	Tank Automotive Research, Development, and Engineering Center
TNT	trinitrotoluene
TR	Technical Report
TWPS	Tactical Water Purification System
UF	ultrafiltration
UFC	Unified Facilities Criteria
URL	Universal Resource Locator
USACE	U.S. Army Corps of Engineers
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USAF	U.S. Air Force
USEPA	U.S. Environmental Protection Agency
WW	wastewater
WWW	World Wide Web

Appendix A: Sustainable Water Usage (AERTA CM-1-02-02)

Environmental Technology Requirement

1. Last Revision Date: 3 November 2006
2. Revision Number: Final Draft
3. Title: Sustainable Water Usage [CM-1-02-02]
4. Technology Team: Compliance [Maps to Sustainable Infrastructure]
5. Previous AERTA Requirement: This is a modified version of previous AERTA requirement "A (2.2.f)", focusing on current Army sustainability needs.
6. Requirement Lead/Proponent: HQ USACE, Mal McLeod 202-761-0632, Malcolm.E.Mcleod@usace.army.mil; ACSIM-FD
7. Statement of User Need: The Army requires the capability to recycle/reuse available water through a variety of innovative ideas and practical applications within buildings and processes including cascade recycle as well as water harvesting, with the ultimate purpose of increasing available supply. Water is often a limited, strategic resource and can impact whether an installation can expand or perform its assigned or additional missions and maintain quality of life. Communities surrounding, upstream, and downstream of military installations are also expanding and can limit the amount of water available for installations. Additionally, there are demands within base camps and theater environments where the value of water may exceed that of fuel, encouraging the application of comprehensive recycle systems.

Nearly all surface waters have been allocated for use, making it difficult to get increased allotments; groundwater extraction occurs faster than recharge; contamination or degradation is occurring or threatened in many areas; and increased concern exists for the natural environment and its maintenance. Droughts and water restrictions are no longer limited to arid and semi-arid regions of the country. Federal requirements mandate best management water conservation practices. Cost of water is constantly escalating.

Reuse of treated sewage effluent for irrigation and use as boiler makeup water are opportunities to derive maximal effect from limited supply.

Graywater (bathing, kitchen, and laundry wastewater) and even blackwater (human wastewater) recycling within buildings for toilet flushing or complete reuse are possibilities. Zero-discharge concepts for industrial processes that use water are additional opportunities resulting in reduction of the amount of wastewater to be treated as industrial or hazardous wastewater. Recycling and reuse of water and/or wastewater, improved water efficiency of existing water consumptive uses, and various other mechanisms, management practices and techniques will enable installations to achieve

The *FY07 Army Environmental Requirements and Technology Assessments* encourages sustainability, proactive efforts to be good neighbors in water-short areas, reducing environmental impacts, and reducing costs.

8. **Key Policy or Regulatory Drivers are:**

- Installation Sustainability Plans of Individual Military Installations.
- Energy Policy Act.
- Strategic Plan for Army Sustainability.
- Army Environmental Policy.
- Army Strategy for the Environment.
- Executive Order 13123.
- Army Energy and Water Campaign Plan for Installations.
- Clean Water Act.
- USACE Campaign Plan.
- Army Science Board Study Report on Water Supply and Management for Army Installations in the Western United States (1988).

9. **Impact if not Addressed:** Costs for water and sewage (including energy requirements) will rapidly escalate as states and the USEPA continue to ratchet up treatment requirements for both potable water and wastewater treatment. Potential mission shifting to other installations may be unattainable due to water restrictions. Increased growth at populous installations may be denied due to unavailable water supply. Moratoriums on sewage connections, for example, have appeared in some communities, effectively stopping expansion. Examples of the impact of a limited water supply, for example, include: Fort Irwin, which produces a limited supply of potable water using high-cost reverse osmosis technology, and which mandates very high levels of water conservation; Fort Bliss, which is partnering in a massive desalination project to ensure an adequate water supply to an expanding regional and installation population base; Fort Sam Houston, which will receive over 10,000 additional personnel under BRAC

in a water-short area; and Fort Bragg, where recently a drought and low river flow forced the installation to purchase water from another source. As an example of the high cost of water, one major Northeast installation pays $3.81 per kgal (1000 gal) for water and $4.25 per kgal of sewage. Many installations pay sewage charges based on the consumption of potable water and in an example of inefficient usage, the above–mentioned installation could pay over $8.00 per kgal for watering landscapes, well over the national average. The Army spends millions of dollars per year for water and wastewater services. For example, Fort Hood and Fort Carson together use nearly 10 million gal/day. While the Army has instituted many water-conserving measures, substantial opportunities remain. Recycling and reusing water enables maximum efficiency from an available water supply and will enable installations to meet their long-term sustainability goals. Savings of millions of dollars and billions of gallons of water per year are achievable.

10. **End User(s) and/or Approver(s):**

- ACSIM, Bill Eng 202-761-0632, William.Eng@us.army.mil.
- IMA, Brian Moyer 703-602-5333, Brian.R.Moyer1@us.army.mil.
- State Department.
- Contingency Operations.
- Fort Irwin, Fort Bliss, Fort Carson, West Point, Fort Ord and other installations and activities in areas where water is in short supply or extremely valuable.

11. **DOTMLPF Analysis Summary:**

- **Doctrine:** A change in Army doctrine will not address this weakness, although encouragement of sustainability goals will help motivate towards the solutions.
- **Operations:** A change in operations alone will not address this weakness, however, operations could be part of the integrated solution.
- **Training:** Training will help address this weakness, but training will benefit through full implementation of technology solutions.
- **Materiel:** Solutions in the form of technology and techniques for achieving recycling/reuse of water are needed.
- **Leadership:** A change in leadership or leadership technique will not address this weakness, but effective leadership can encourage implementation of solutions.
- **Personnel:** A change in number or type of personnel will not address this weakness.

- **Facilities:** A modification in facilities or facilities processes alone will not address this weakness, but will be part of the integrated technology and technique solution set.

Based on this analysis, a materiel solution, supported by DOTLPF is the preferred solution for implementing water reuse/recycle on installations.

Appendix B: Challenges and Water Technology Objectives at Fixed Facilities

By Richard Scholze, Construction Engineering Research Laboratory (CERL)

Introduction

When we have enough water, it is not a concern. But when there is a drought or when communities begin rationing water consumption, concern sets in, which turns to panic when reservoir levels fall to new lows. Droughts and low water supply are not limited to the arid and semi-arid West, where obvious water shortages currently exist; they occur throughout the nation. Water costs are rapidly rising; supplies are becoming increasingly short; restrictions exist on consumption and disposal; and Federal and Army (DOD) mandates have been initiated to reduce annual consumption. Military installations have strong interest in using resources such as water efficiently. In general, installations are charged with being stewards of the environment and efficiently using valuable natural resources such as water. When installations become “water-limited,” the condition potentially impacts mission changes and execution. Installations must be able to stand alone and to execute their mission without being constrained by the competing needs and interests of surrounding communities.

Water supply is finite. Although it is essential to squeeze maximum use out of the existing supply, that supply is seldom used efficiently. In fact, 90 percent of potable water consumed on installations goes for non-potable uses that may be well served by secondary water sources, by captured rainwater (the primary feasible, cost-effective, source for additional water), or efficiently reused/recycled water. (Of course, state water laws and regulations may impact what can actually be achieved at specific installations.)

Strong programs in water management and water efficiency at individual installations may be augmented by approaches already in use. Many regions find alternative sources of water by purifying impaired waters, by increasing water reuse and recycling, and by desalination of brackish groundwater and seawater. Surface water may be supplemented with reclaimed water, aquifer storage and recovery, stormwater reuse, rainwater

harvesting, aquifer recharge, and off-line reservoir storage. Available water sources may be expanded by using such currently unharvested or unused water as irrigation tailwaters, produced water from energy production, brackish water, and air-conditioning condensate.

Current situation for installations

Military installations exist throughout the United States and the world, in every climate zone and geographic area. Installations vary widely in age and in size from small Reserve facilities to many installations that occupy over 100,000 acres with populations exceeding 50,000 residents and staff. Buildings on installations are usually under central control and the master planning division of the installation maintains a schedule to phase-in new construction and demolish old buildings. Although the military tries to maintain and upgrade utility systems on a regular basis, the reality is that many utility collection and distribution systems are more than 50 years old. (Due to their visibility, treatment plants receive slightly better attention.) Moreover, military installations have hundreds of historic buildings and substantial stocks of World War II vintage facilities.

The Public Works Directorate or similar entity has traditionally been responsible for keeping installations functional and operational, and for controlling all real estate within installation boundaries. However, some installations have privatized utilities including water and wastewater. Also, with the advent of the Residential Communities Initiative (RCI), private companies sometimes provide family housing, including utility services, on a long-term property lease, which takes direct control away from the installation.

Installation water and wastewater services cover a wide range of operations from the provision of potable water, to operation of surface water and groundwater treatment facilities, to purchase of utility services as a commodity, to contractual operations on the installation in which the installation maintains ownership. Wastewater treatment is similar; wastewater treatment plants vary in complexity from trickling filter facilities to state-of-the-art membrane bioreactors (MBRs) and advanced treatment facilities to reduce nutrients. Additionally, remote site facilities (training ranges, recreation areas, etc.) can have small individual wells that provide potable water to package treatment plants and septic tanks or vault toilets for wastewater.

Water reuse is necessary to meet fluctuations in water demand as populations shift in wartime: units move in and out, industrial production ramps up and/or cycles. For example, Fort Bliss, Fort Sam Houston, and Fort Bragg have rapidly expanding populations. Water short installations such as Fort Irwin supplement their limited water supply with very expensive reverse osmosis. Fort Huachuca has been under community and outside agency pressure to minimize water consumption.

Policy drivers that encourage installations to pursue water reuse and conservation include: Installation Sustainability Plans; the Strategic Plan for Army Sustainability; Army Environmental Policy; the Army Strategy for the Environment; the Army Energy and Campaign Plan for Installations; Water Conservation Goals; the Clean Water Act; the Energy Policy Act; Leadership in Energy and Environmental Design (LEED) requirements that all new construction achieve at least a "Silver" rating; and Executive Order 13423, which requires 2 percent per year per installation reductions in potable water consumption among others.

Opportunities to increase available water and water efficiency

Water reuse

Background

Water reuse is a global phenomenon and has been rapidly expanding. A variety of factors drive water reuse and require additional water supply sources. The two most frequent motivations are the need to overcome water scarcity (which is expected to worsen), and to meet environmental protection requirements. Others include: drought; increasing population; higher municipal, industrial, and agricultural demand; dependence on a single source of supply; and others. Additional location-specific drivers might include energy savings, local control of the water supply, reliability of supply, and economic enhancement from jobs creation and supply of a new water resource for commercial and industrial development.

Current reuse levels in the United States (nationwide) are 1.5 percent (Sheikh 2007). About 90 percent of water reuse occurs in four states (Arizona, California, Florida, and Texas). Other states (Washington, Oregon, Nevada, Colorado, New Mexico Georgia, Virginia, Maryland, and Pennsylvania) are also becoming major participants. The primary use of recycled water is for irrigation, and future uses are shifting toward groundwater recharge and industrial applications.

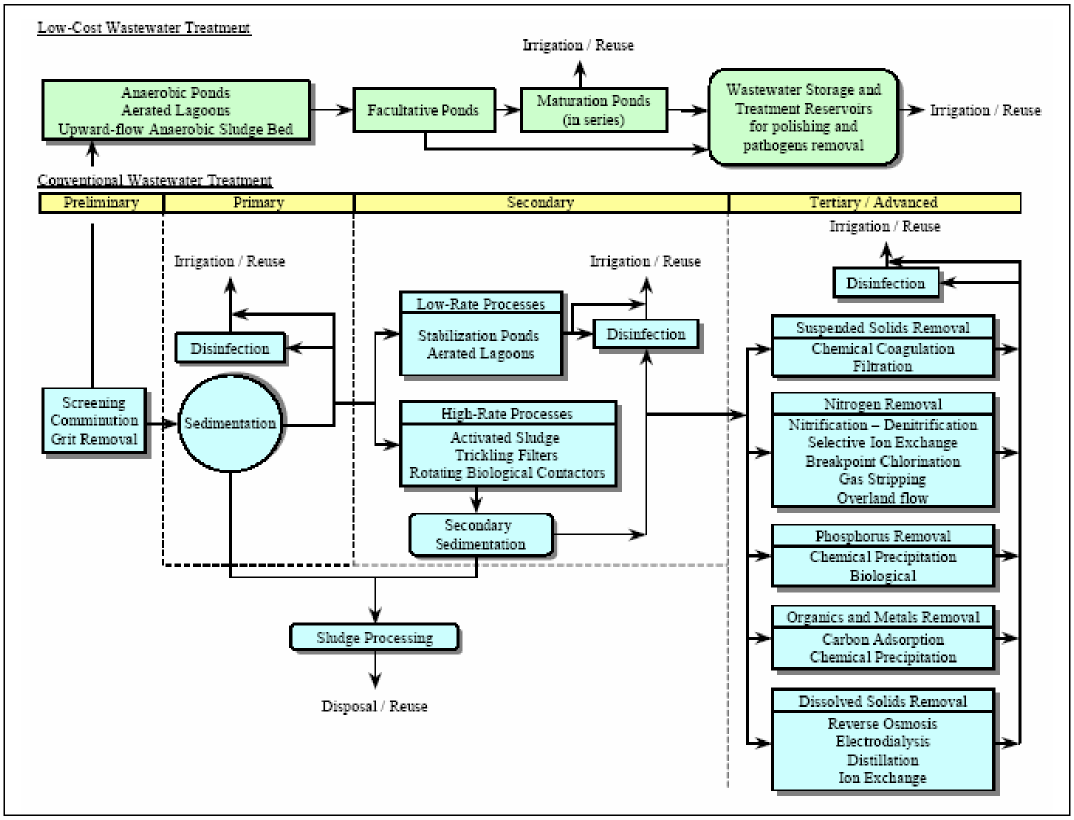

Figure D1. Wastewater reuse path.

Approximately 11.2 percent of municipal wastewater effluent in the United States is reclaimed and beneficially reused. It is projected that water reuse will rise to 12 billion gal/day (bgd) by 2015 from 3.9 bgd in 2007 in the United States alone. Figure D1 (from Foley 2007 citing Radcliffe 2004) shows a variety of pathways that can be taken at a wastewater treatment plant before reuse.

Benefits of water reuse

Among the benefits of wastewater reuse for the future are that:

- Wastewater is a drought-proof water resource that augments existing supply.
- Wastewater is the only water source that automatically increases with economic and population growth.
- The need for treated wastewater/effluent is usually near the source.
- Drought is indefinite; drought length and location are unknown.
- Demand is growing for water.
- Regulatory requirements and contaminant issues are increasing.
- Reduce nutrient and contaminant loads to waterways.

- Water reuse recovers/recycles nutrients back to agricultural land and minimizes the use of chemical fertilizers.
- Water reuse reduces stress on groundwater aquifers and surface waters.
- Water reuse provides environmental flows and wetlands maintenance.
- Water reuse improves water security for both potable and non-potable uses.
- Water reuse provides an additional water source for firefighting.
- Water reuse provides a dependable source of supply.
- Water reuse is locally controlled.
- Water reuse is environmentally friendly.
- Water reuse requires low or no capital costs.

Significant trends in water reuse

- Reuse is gaining in prominence around the globe.
- Major technology pushes include membrane bioreactors (MBRs) for treatment and advanced oxidation processes (AOPs) for disinfection.
- Global focus for research plus reuse is now on the Federal radar screen.
- Progress is being made on the indirect potable reuse front.

Applications

Since direct potable reuse is not practiced in the United States, the water reuse focus is on non-potable reuse. For non-potable reuse, it is essential to match reclaimed water quality with its intended use. The most important aspect of water reuse is the protection of human health. For example: irrigation may require undisinfected secondary treatment of the water, disinfected secondary treatment, or disinfected tertiary level of treatment, depending on the type of facility or crops being grown. Cooling tower and air-conditioning use may need disinfected secondary or tertiary treated wastewater. Recreational contact may require disinfected tertiary treatment. Groundwater recharge may require disinfected tertiary treatment. Non-food bearing trees can use undisinfected secondary effluent from a wastewater treatment plant.

The lowest quality water is generally directed towards landscape irrigation. This is one of the best uses of reclaimed water, on installation parade grounds, recreation fields, landscaped areas, golf courses, and housing areas. Following the tenets of sustainability, the best practice is to cascade water usage where water is used once and then reused or recycled to a use that requires water of a lesser quality. Wastewater can also be collected at

the wastewater treatment plant and treated to various levels of quality and transported via an independent distribution system for appropriate purposes. It is important to have dual distribution systems, which is easily accomplished with new construction.

In addition to irrigation, industrial operations (central energy facilities, wet scrubbers, and boiler makeup) are major potential consumers of reused water. Installation central vehicle wash facilities that use recycled wastewater can save hundreds of millions of gallons per year. Toilet flushing could use treated wastewater, or rainwater captured from rooftops (with minimal treatment). As water supplies become scarce and more expensive, utilities, and industry must find more innovative ways of reusing water supplies to reduce their total water demand. They should plan to incorporate water reuse into the design of their new plants, whenever possible. It will be more economical to implement reuse from the initial stages of plant operation, rather than to retrofit reuse into the processes at a later time.

Other actual or potential water reuse applications for military installations include: man-made wetlands, groundwater recharge, stream augmentation, aquifer storage and recovery, and saltwater intrusion barriers along coasts (Table D1).

Table D1. Categories of water reuse.

Category	Typical Application
Irrigation	Parks School yards Highway medians Golf courses Cemeteries Parade grounds Athletic fields Building landscapes Crops or vegetable gardens
Industrial recycling and reuse	Cooling water Boiler feed Process water Construction
Groundwater recharge	Groundwater recharge Saltwater intrusion control Subsidence control
Recreational/ environmental uses	Lakes and ponds Marsh enhancement Streamflow augmentation Fisheries
Nonpotable installation uses	Fire protection Air conditioning Toilet flushing Water features

Regulations and criteria

In the United States, no Federal regulations or standards cover water reclamation and reuse. This responsibility falls to the states, many of which now require reuse feasibility studies for expanding municipalities. The majority of states and the USEPA have issued guidelines and regulations addressing recommended treatment processes, water quality limits, monitoring, setback distances, and other controls.

Regulations and guidelines vary depending on types of reuse, from most stringent to least: indirect potable reuse; agricultural reuse on food crops; unrestricted recreational reuse; unrestricted urban irrigation reuse, restricted urban irrigation reuse, restricted recreational reuse, industrial reuse, environmental reuse; and agricultural reuse on non-food crops.

The “best available technology” in most of the world is membranes. Costs are dropping as membranes become more efficient. However, energy is becoming more expensive.

Future trends

- Indirect potable reuse is inevitable.
- Increased desalination — both brackish groundwater and seawater — also inevitable.
- Efficacy of technology is not an issue.

Produced water

Approximately 1.5 bgd of “co-produced water” (water produced during oil and gas extraction) is generated in the United States. Co-produced water can contain gas/oil ratios that range from a low of 5 to 1 up to a high of 100 to 1; and it can also contain a range of inorganic, organic, and hydrocarbon contaminants in a wide range of concentrations. U.S. co-produced water can vary in total dissolved solids (TDS); water with less than 10,000 mg/L can make good candidate source water; water that exceeds 60,000 mg/L makes poor candidate source.

Co-produced water may be classified as non-tributary water. The Bureau of Reclamation is working with Indian Trusts, states, and rural water interests to investigate potential specific uses for discharge to streams, agricultural use or municipal and industrial use. They have an extensive program examining various treatment processes. One specific area of interest is ceramic membranes, which are being evaluated for viability for pretreatment to RO, nanofiltration, and electrodialysis. Research includes optimization of flux and recovery, evaluation of different operating regimes, demonstration of organic contaminant removal and characterization of membrane surface. The processes involved to treat produced water are not discussed in this paper as produced water is not expected to play a major role on military installations. However, substantial research program is underway at other agencies such as the Bureau of Reclamation.

Desalination

Although Increasing salinity levels in surface and groundwater supplies (due to human activity, repeated use and drought) have created a pressing need for affordable desalination, only a small number of plants have been built in the United States. The most prohibitive factor has historically been the higher cost relative to other water supply options, but recent technological advancements and industry competition have lowered the cost of advanced treatment technologies to affordable (although relatively expensive) levels. While high demand for this technology during the last 2 years has rapidly outpaced supply, causing prices to rise sharply, the process should correct as future supply capacity increases.

Important areas to be aware of are advancements in membrane development, process efficiency, and energy reductions. (There is a strong correlation between complex treatment processes and energy demands.) Energy requirements for desalination have been dropping in the amount of energy required to produce a given amount of product water.

Monterey Bay, CA has had nine entities propose desalination projects (Bodensteiner 2007). As a response for drought proofing the area and reductions in groundwater permitted capacity, Tampa Bay put in a 25 mgd desalination plant co-located with a power plant that uses once-through water for cooling and as the source water for the desalination plant and for concentrate dilution prior to discharge. This approach is being used nationally. A brackish water desalination facility is currently under construction in New England (Clunie et al. 2007) that will produce 5 mgd of potable water in southeastern Massachusetts. Many other plants are being planned using both brackish groundwater and seawater.

El Paso, TX has recently completed a 27.5 mgd RO desalination plant to combat brackish groundwater intrusion to fresh water wells and to produce potable water. The facility is located on Fort Bliss, and the Army supplied some of the funding. A critical issue is disposal of concentrate produced by the process. The utility opted to use deep well disposal (Hutchison 2007).

Fort Irwin, CA is building a zero liquid and solid discharge water treatment plant to treat local brackish water to potable standards. The facility will be a electrodialysis reversal facility producing 6 mgd. Overall water recovery from the facility will be greater than 99 percent with a brine

waste stream of 0.3 percent, which may be disposed as a solid by conversion through an evaporation pond (Mavis et al. 2007).

Inland regions face limitations with desalination and environmental constraints associated with membrane waste (concentrate) disposal. One approach (Bond 2007) involved treating the concentrate from a primary RO in a fluidized bed crystallizer to remove recovery-limiting salts, then passing the treated concentrate through a secondary RO for further product water recovery. After the secondary RO, the total recovery for most brackish water applications is expected to be 95 to 98 percent. The final concentrate volume would be reduced sufficiently to allow evaporation ponds, enhanced evaporation systems, or thermal desalination to be used for the final separation of water from the salts at a much lower cost. Another alternative is to use the brine to create or enhance productive brackish marsh habitat. There has been a long history of wetlands treatment of industrial, municipal, and agricultural effluents and stormwater runoff, therefore a technological basis exists for investigating wetlands reuse of concentrate.

Satellite reclamation plants

Satellite treatment, also known as “sewer mining” is defined as water treatment at a facility remote from a central treatment plant that takes water from the collection system and produces reclaimed water for local use while discharging residuals back to the collection system for treatment at the central facility. Locating reclamation facilities close to reuse customers significantly reduces cost of reclaimed water distribution and allows reclaimed water quality to better match customer needs (Reardon et al. 2007). For example, sewer mining with small scale treatment plants (Figure D2) can withdraw sewage from a sewer, treat it to an appropriate standard and then use it as needed for irrigation (PMSEIC 2003).

MBRs are becoming the preferred treatment technology for the newest satellite facilities. Advances in this technology have facilitated remote operations with part-time staffing, in plants that have a minimal footprint and that reduce distribution costs. Disadvantages include higher power demands, increased complexity, and greater annual costs (Reardon et al. 2007).

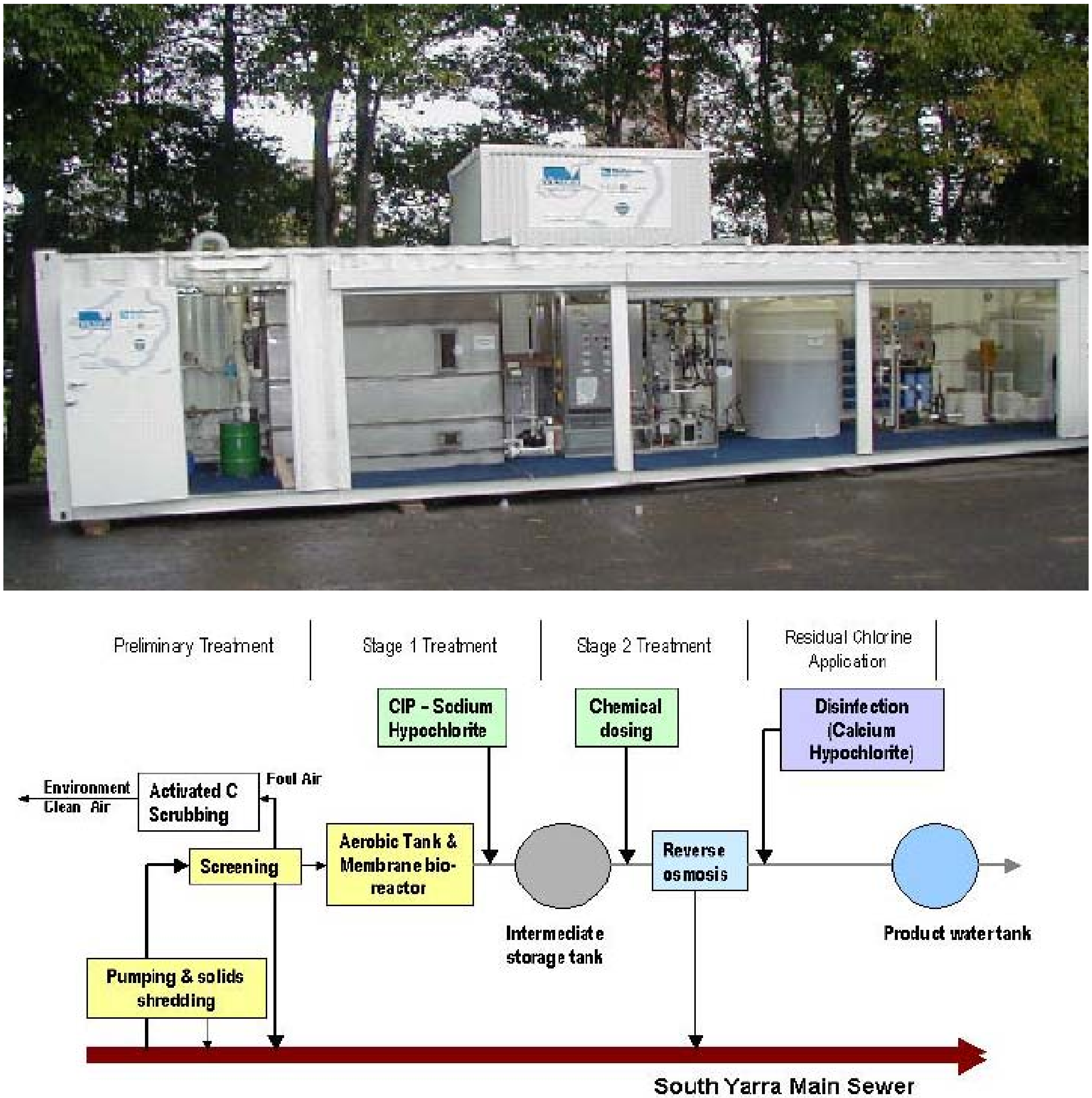

Figure D2. Satellite reclamation plant, pictured (above), schematically represented (below).

Soil-aquifer treatment

In SAT, treated wastewater is ponded at the ground surface and allowed to percolate through the vadose zone to an underlying groundwater aquifer. As the wastewater passes through the vadose zone, it is treated by natural processes including sorption, bioremediation, and filtration. As the water reaches the underlying aquifer, the aquifer is recharged and can be used as a water source.

SAT is currently in use in the United States as a technology for the indirect, potable reuse of wastewater, particularly in arid regions such as Arizona and California. Recharging an aquifer using SAT may help to maintain the aquifer's viability and health in regard to the environment; and

contribute to sustained stream flows, the health of overlying vegetation, and the sustainability of life in the aquifer in both hydrogeologic and legal-environmental terms (Engleson and Cunningham 2007.

Riverbank filtration and artificial recharge and recovery

Riverbank filtration (RBF) is a natural process that had been used for public and industrial water supply in Europe for more than a century and for nearly half a century in the United States to treat a variety of waterborne contaminants. In the United States, RBF is becoming increasingly recognized over the past years as a viable option for water utilities required to meet stringent regulations for the direct use of surface water of impaired quality. There is also evidence that RBF is an effective pretreatment in removing pathogens, nutrients, and total organic carbon and in decreasing the disinfection by-product formation potential, re-growth potential for distribution systems, and fouling potential for subsequent membrane treatment. More recently, it has been reported that RBF can effectively attenuate organic micropollutants of concern (Hoppe et al. 2007)

Rainwater harvesting

Rainwater harvesting (RWH) usually refers to the collection of rainfall runoff from roof surfaces in cisterns for domestic use; however, it may also include surface water collection in small tanks or impoundments for livestock watering and landscape irrigation. The Texas Water Development Board (2005) has produced an excellent resource document on the subject.

Among the benefits of RWH are that rainwater is free of chemicals and/or dissolved salts. Rainwater is naturally soft, can be used for household purposes without water softening, and is ideal for those on low-sodium diets. Plants also respond well to rainwater better than to municipal water due to the absence of added chemicals.

RWH is increasing in many parts of the United States as well as around the world. For example, Australia had been encouraging urbanites to install tanks to catch rainwater from roofs for supplemental garden watering, but tank size considerations made the exercise uneconomic. A different approach being currently taken is to use tank water for toilet flushing and for hot water supply for general use. With these relatively constant uses throughout the year and the potable distribution system as a backup,

it is possible to significantly reduce demand on the city system with modestly sized tanks (PMSEIC 2003).

For every inch of rain, about 600 gal of water can be collected from 1000 sq ft of roof area. A typical home with 2000 sq ft of roof area can yield up to 40,000 gal/yr assuming full retention and capture of 33 in. of rain, water that would otherwise run off. If properly managed, a RWH system could provide up to 100 gal/day for a typical home. The cost of a RWH system depends primarily on the size of the cistern used for storage. A RWH system for a home can cost anywhere from $5,000-$8,000, which includes the guttering for leading the water to the cistern, and costs for the cistern, pump, and treatment system.

Treatment for rainwater depends on the intended end use and three main types are used: filtration, thermal disinfection, and ultraviolet (UV) treatment. Treatment provides a barrier to micro-organisms and both micro- and ultra-filtration are used. Thermal disinfection using the hot water service is currently being investigated, and results have shown that bacteria do die off at temperatures relevant to domestic hot water systems. None of the treatment systems provide residual disinfection, and all have associated maintenance and replacement requirements. Awareness of volume in the tanks is essential and a variety of innovative float systems are available (Diaper et al. 2007).

Collection systems employ gutter guards, first flush diverters, and inlet filters to reduce ingress of contaminants such as leaves, animal fecal waste, and airborne pollutants. First-flush devices reduced rainwater tank contaminant levels at the cost of collection efficiency. Rainwater systems involve collection, storage, treatment, and distribution technologies. The three main types of collection systems are:

- Dry systems (most common) — all pipes are above ground.
- Wet systems — collection pipes are buried to reduce aesthetic impact and pipes contain a residual volume of water.
- Siphonic systems — the collection system is designed to maximize pipe flow rates using siphonic full bore flow (Diaper et al. 2007).

Distribution of rainwater is usually via a pump, although in certain situations, end uses can be gravity fed. An automatic diverter device, in which mains pressure is used when backup water is required. Regardless of the complexity of the system, the domestic rainwater harvesting system comprises six basic components:

1. *Catchment surface*, from which rainfall runs off. (Due to leaching of toxins, composite shingles are not appropriate for potable systems.)
2. *Gutters and downspouts* that channel water from the roof to the tank. For potable water system, lead cannot be used as gutter solder.
3. *Leaf screens, first-flush diverters, and roof washers*, which remove debris and dust from the captured rainwater before it goes to the tank.
4. *Storage tanks*, also called cisterns, which is the most expensive component of the rainwater harvesting system. The size of storage tanks or cisterns is dictated by the rainwater supply (local precipitation), the demand, the projected length of dry spells without rain, the catchment surface area, aesthetics, personal preference and budget. Storage tank basics include:
    a. Storage tanks must be opaque to inhibit algae growth
    b. Storage tanks for potable systems must never have been used to store toxic materials.
    c. Tanks must be covered and vents screened to discourage mosquito breeding.
    d. Tanks used for potable systems must be accessible for cleaning.
5. *Treatment systems* (for potable use), which (beyond the leaf screen and roof washer) is necessary to remove sediment and disease-causing pathogens from stored water. Treatment generally consists of filtration and disinfection processes series before distribution to ensure health and safety. Treatment systems can include:
    a. Cartridge filters and ultraviolet (UV) light
    b. Ozone
    c. Membrane filtration
    d. Chlorination
6. *Delivery system*, which is usually gravity-fed or pumped to the end use.

From a financial perspective, the installation and maintenance costs of a rainwater harvesting system for potable water cannot compete with water supplied by a central utility, but is often cost-competitive with installation of a well in rural settings

Stormwater capture and use

Stormwater is the surface runoff from all pervious and impervious areas and differs in quality from rainwater. The components of a stormwater harvesting system should provide five core functions:

- Collection.
- Treatment.
- Storage.

- Flood and environmental flow protection.
- Distribution to end users.

Stormwater is collected via drainage systems and is generally diverted to stormwater collection pipes. Few stormwater technologies are designed specifically for household-scale application. To make stormwater suitable for use as a substitute for municipal potable water supply, technologies, and techniques used need to deliver higher and more consistent levels of treatment. A technical guidance for stormwater treatment and harvesting (Institute for Sustainable Water Resources 2006) suggest UV as a preferred disinfection technique, non-seasonal end uses to minimize storage requirements, and no requirement for closed storages to minimize evaporation. The systems also need to be robust and provide a buffer against quality and quantity variability (Diaper et al. 2007).

For example, Sydney, Australia, Olympic Park uses recycled water from sewage and stormwater to service 20,000 people for toilet flushing; washing clothes; washing cars, windows, and brickwork; washing pets; filling ornamental water features; firefighting and watering of parklands, lawns, gardens (including vegetable), and playing fields (PMSEIC 2003). This saves about 50 percent of drinking water required and with 100 percent of wastewater recycled, reduces discharge to the ocean and controls stormwater pollution.

Figure D3 shows a stormwater collection and treatment technique appropriate to cluster or subdivision scale that can overcome the storage requirement, is aquifer storage and recovery (ASR). The use of this method is dependent on the local geology and accessibility of the aquifer. In addition to the general advantages of stormwater use, ASR also has the benefits of potential reduction in groundwater salinity, reduced storage costs and storage that does not take up land area. ASR can also be used for the storage of wastewater (Diaper et al. 2007). An example high-density residential development in Australia, Atherton gardens, has four high-rise towers. There are four water systems retrofitted: two stormwater, one graywater and one rainwater collection system. The stormwater systems recover water for passive landscape irrigation and treat it before discharge into the stormwater drain reducing contaminant loads. The graywater system collects laundry graywater and, after coarse filtering, flows to a landscape feature wetland. The rainwater system collects from the roof of one of the towers to be used for garden irrigation.

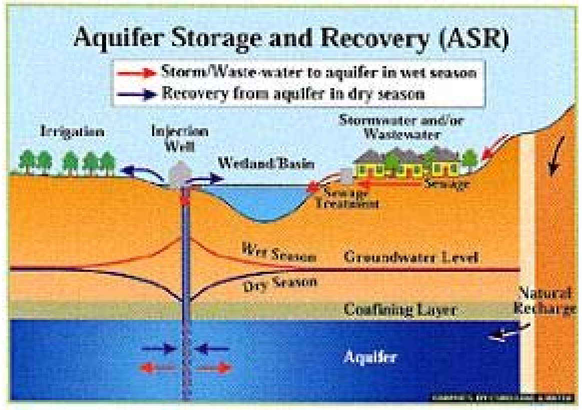

Figure D3. Aquifer storage and recovery.

Low impact development

Sustainable stormwater storage should also be considered in the context of Low Impact Development (LID). The LID approach to stormwater management follows basic natural principles: manage rainfall as near the source as possible using micro-scale controls. LID's goal is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. LID addresses stormwater through small, cost-effective features at lot or local level. Components include open space, rooftops, streetscapes, parking lots, sidewalks, and medians and can save money over conventional approaches by reducing infrastructure and site preparation work (up to 25 or 30 percent) through reductions in clearing, grading, pipes, ponds, inlets, curbs, and paving, and through potential space recovery for other beneficial uses.

The five basic steps in a LID design are:

1. Conservation.
2. Minimization.
3. Runoff concentration.
4. Distributed integrated management.
5. Pollution prevention.

LID encourages conservation of forests, natural vegetation, streams, wetlands, and open space. These features should be multifunctional. Minimization techniques reduce hydrologic impacts or maintain hydrologic function (for example, reduced clearing and grading, saving infiltrable soils, and limiting lot disturbance). Open drainage systems, flatter slopes, dispersed drainage, longer flow paths, vegetative swales, and maximized sheet flow slow down runoff. Slower runoff reduces discharges and encourages more infiltration and evaporation. Use of distributed integrated

management practices includes practices to provide retention, detention, filtration, and storage of runoff for various uses. Techniques include bioretention, depression storage, rooftop storage, street, and parking lot storage, compact weir outfalls to dissipate energy, and soil amendments to increase storage. Reducing pollutants to the environment helps improve water quality.

Examples of LID include: bioretention or rain gardens, constructed wetlands, water quality swales, vegetated roof systems, and porous pavement with subsurface infiltration beds.

Additional information is available at an EPA-funded website: http://www.lid-stormwater.net. A literature review is available at www.epa.gov/owow/nps.lid.pdf. An excellent overview of LID has been published by the Puget Sound Action Team and is on-line at http://www.psp.wa.gov/downloads/LID/LID_manual2005.pdf.

A Unified Facilities Design manual for LID for military installations (UFC 3-210-10 is available at: http://www.wbdg.org/references/ccbdoc.

Graywater use

The main sources of graywater are the bathroom, laundry, and kitchen. Most graywater collect and treat graywater from the bathroom and laundry only, as kitchen wastewater contains higher concentrations of gross contaminants and fats, oils, and greases. Graywater offer an advantage over rainwater systems of continuous supply during dry periods. The potential water savings associated with graywater treatment and use are well documented and depend primarily on end use. At least a 20 percent savings could be expected by using graywater for toilet flushing and irrigation (Diaper et al. 2007).

The two basic types of graywater system are the: (1) direct diversion systems, and (2) collection, treatment, storage, and distribution systems that produce higher quality water. Direct diversion systems are available for subsurface irrigation and toilet flushing, while graywater treatment systems can be used for gardens, toilets, and potentially laundries. It is critical that the quality of graywater be matched to its end use; certain graywater source streams can contain human pathogens, nutrients, dissolved salts, and biodegradable organics. Many graywater recycling systems are available; costs vary depending on building design, space availability, and piping requirements (Diaper et al. 2007).

In-building uses such as hot water services, toilets, laundry of water from multi-purpose storages (such as modular fence and wall panels that store water), or flexible bladder tanks and eaves storages, allow detention where space is unavailable for conventional cylindrical tanks (Dillon et al. 2004).

Water conservation/water efficiency

All military installations should have a water management plan that addresses how water is used, how it is accounted for, and what is being done to improve efficiency and supply. They are also in the process of/or have completed implementing four of the Federal energy management program's best management practices to improve water efficiency:

- Public information and education program.
- Distribution system audits, leak detection and repair.
- Water efficient landscaping.
- Toilets and urinals.
- Faucets and showerheads.
- Boiler/steam systems.
- Single-pass cooling systems.
- Cooling tower systems.
- Miscellaneous water-using processes.
- Water reuse and recycling.

Usually, the largest consumptive activity on most installations is irrigation (on parade grounds, parks, and recreation areas, athletic fields, etc.). Types of buildings that consume water include institutional, industrial, and barracks, and some of the largest water consumers are hospitals, laboratories, and dining facilities. Strategies that can reduce water use in thee types of buildings include: low flow, dual flush and high efficiency toilets, and waterless urinals in the toilets and urinals category; water audits and leak surveys; pre-rinse valves, alternative garbage disposal options, boilerless food steamers, water-conserving appliances in dining facilities; and use of air conditioner condensate as irrigation water.

Smart sewers and human waste separation

"Smart sewers" reduce infiltration by using longer pipe lengths with fused or solvent joints for pressure or vacuum transport of wastewater, reducing the number of manholes, and using curved pipes and drainage requirements to discourage connection of sanitary wastewater to storm sewers. This permits smaller pipes, and smaller treatment and pumping systems.

Another emerging technology is a toilet bowl that separates urine and feces. Other innovations could include vacuum, low flush, and composting toilets in combination with urine separation. Fecal waste could then be transported by vacuum system and urine stored in household storage tanks or sent to regional plants through smaller diameter sewers.

Military experience

Army

Fort Huachuca is located in the Upper San Pedro Basin (USPB), one of the last free-flowing rivers in the southwest, habitat for several threatened or endangered species, and designated as the first riparian national conservation area. The residents of the USPB, including Fort Huachuca, depend entirely on groundwater to meet their water needs. This competition for limited groundwater resources is the reason why Congress passed legislation (Section 321 of the 2006 Defense Appropriations Bill) requiring that steps be taken to address groundwater overdraft in the USPB.

Fort Huachuca has made tremendous progress in its efforts to mitigate its impacts on the regional groundwater system that, in part, supports the San Pedro river, including water conservation initiatives and education, aggressive leak detection and repair, reuse, and recharge of treated effluent, and, in partnership with the nature conservancy, retirement of agricultural pumping through purchase of conservation easements has been to reduce the Fort's net groundwater consumption by approximately 2272 acre-feet per year (71 percent) since 1989.

In addition, a regional consortium of Federal, state, and local agencies, and nongovernmental organizations known as the upper San Pedro partnership (USPP) has helped implement various projects and fund research that furthers our understanding of the regional hydrologic cycle. To date, the USPP and its member agencies have implemented water conservation and recharge projects totaling 4000 acre-feet/year, that although have not entirely mitigated the groundwater overdraft, have at least kept it in check in the face of sun-induced growth.

Further progress must be made to address the regional groundwater deficit to protect the San Pedro river and ensure the viability of Fort Huachuca, i.e., the implementation of regional water projects such as spatially distributed treated effluent and stormwater recharge facilities, and local (i.e., site-specific) projects incorporating advances in water conservation

technology, and augmentation of groundwater resources with alternative water sources such as harvested rain water.

Air Force

At Mountain Home AFB, a former drinking water well contaminated with nitrates was converted to the single water source for irrigating the golf course. This served as a remediation effort to clean up the nitrates and fertilize the course while using a non-potable water source.

A leak detection survey at Kirtland Air Force Base over a 108-mile water distribution system identified 31 leaks, which were then repaired. This was estimated to save almost 175 million gallons of water per year—about 16 percent of Kirtland's total water use in fiscal year 2006 (FY06), valued at more than $328,000. Installation of a computerized Landscape Master Control System on 27.5 acres to control irrigation, runoff, and leaks has the potential to save more than 11 million additional gallons per year.

The engineering team at Fairchild Air Force Base instituted a comprehensive water planning, management, leak detection, and repair program that reduced water use by 27 percent. The team investigated and implemented 10 energy measures to reduce the leakage rate on base, including distribution system audits and repairs, installation of water-efficient restroom equipment, replacement of boiler and steam systems, and public education. These efforts reduced water use by 27 percent over several years so that unaccounted-for-water now totals only 3 percent of all water used by the base.

Luke AFB achieved an annual water consumption reduction rate of over 66 million gallons by restricting water use through housing regulation and education, and incorporation of "Xeriscaping," a technique for using plants and grasses native to the area that require less water to sustain growth.

Luke AFB has also maintained a reclaimed wastewater reuse permit that has allowed the installation to reuse over 500,000 gallons of effluent per day to irrigate the installation's golf course, parks, and athletic fields. During the summer months, Luke reclaims 100 percent of its wastewater (an average of 17.5 million gal/month), making it a "zero discharge" facility.

Pillar Point Air Force Station (AFS) is implementing Low Impact Development (LID) Concepts (e.g., bioswales) to effectively retain nearly 80 percent percent of stormwater run-off on-site.

The installation of adjustable arc irrigation assemblies for golf course at Vandenberg AFB golf course irrigates precisely targeted playable surfaces, saving 5 million gallons of water ($5400) annually.

Los Angeles AFB purchases reclaimed water for use in facility toilets/urinals and landscape irrigation, saving $27,397 in utility costs annually.

Army and Air Force

Reclaimed water is used for irrigation at multiple installations, both Army and Air Force. Reclaimed water is also used for cooling tower makeup. Representative bases include Fort Sam Houston, Beale, and Mountain Home AFB.

Waterless urinals have been widely demonstrated throughout the Army and Air Force with positive results and heavily encouraged in Army new construction to meet LEED goals.

Summary

Explosive growth, diminishing fresh water supplies, saltwater intrusion, evapotranspiration, brackish water treatment and concentrate disposal, environmental stewardship, and disinfection issues all are making headlines.

Water reuse, water efficiency and full use and expansion of existing water supplies are a necessity for the country to continue growth. More complete use of water through activities such as water reuse and reclamation, use of brackish water and other saline sources in inland areas through membrane processes, capture of stormwater and rainwater for beneficial use on-site or on a regional basis, use of graywater on-site, sewer mining, and capture and use of produced waters are all opportunities, as is expanded use of indirect potable reuse through activities such as riverbank filtration, aquifer recharge, and other approaches.

Supporting research is taking place at numerous Federal agencies, universities, and research centers and industry to support expansion of water

supplies and stretching them to get the maximum beneficial use from them, reduce costs (capital and operation and maintenance) and concepts are evolving to use water at the level of treatment required for a given purpose rather than treating to the highest level.

Future research/demonstrations

- Demonstration of Graywater Alternatives.
- Demonstration of Rainwater Harvesting on Installations.
- Comprehensive Evaluation of Water Use at Installations.
- Model for Cascade Options for Water Reuse.
- LID Alternatives to Reuse Water.
- Constructed Wetlands for Treatment and Reuse.

References

Bodensteiner, Scott, Matt Zinkl, Jenner McCloskey, and Suzanne Brander. 2007. "Collateral benefits of desalination to the San Francisco Bay aquatic environment." *Proceedings of the Water Reuse Symposium 2007*. Alexandria, VA: WateReuse Association.

Bond, Rick. 2007. "Reducing the costs for desalination with zero liquid discharge." *Proceedings of the Water Reuse Symposium 2007*. Alexandria, VA: WateReuse Association.

Clunie, William, Betsy Shreve-Gibb, and Larry VandeVenter. 2007. "Reverse osmosis concentrate disposal to environmentally sensitive tidal estuary: A case study." *Proceedings of the Water Reuse Symposium 2007*. Alexandria, VA: WateReuse Association.

Department of Defense (DOD). 2004. *Low Impact Development. Unified Facilities Criteria* (UFC) 3-210-10, accessed 07 November 2008, http://www.wbdg.org/ccb/DOD/UFC/ufc_3_210_10.pdf

Diaper, C., G. Tjandraatmadja, and S. Kenway. 2007. *Sustainable Subdivisions: Review of Technologies for Integrated Water Service*. Brisbane, Australia: Cooperative Research Centre for Construction Innovation

Dillon, P., D. Ellis, and J. VanLeeuwen. 2004 *Australian Water Conservation and Reuse Research Program — Outcomes of Reviews and a New National Portfolio of Innovative Projects*. Australian Water Conservation and Reuse Research Program.

Engleson, Joel David, and Jeffrey Cunningham. 2007. "Comprehensive numerical model of soil-aquifer treatment." *Proceedings of the Water Reuse Symposium 2007*. Alexandria, VA: WateReuse Association.

Hoppe, Christiane, Jörg E. Drewes, Gretchen Oldham, Uwe Hħbner, Rod Brauer, and Kim Thompson. 2007. "Sustainable removal of bulk organics and organic micropollutants through riverbank filtration (RBF) and artificial recharge and recovery (ARR)." *Proceedings of the Water Reuse Symposium 2007*. Alexandria, VA: WateReuse Association.

Hutchison, William R. 2007. "El Paso brackish groundwater desalination project: Initial operation." *Proceedings of the Water Reuse Symposium 2007*. Alexandria, VA: WateReuse Association.

Institute for Sustainable Water Resources. 2006. *Integrated Stormwater Treatment and Harvesting: Technical Guidance Report*. ISWR report 06/05.

Low Impact Development Center, Inc. "Low Impact Development (LID)." *Urban Design Tools*, Website, accessed 07 November 2008 http://www.lid-stormwater.net/

Mavis, James D., Jr. Maryam Alborzfar, and Scott Boettcher. 2007. "Process design considerations for brackish water treatment." *Proceedings of the Water Reuse Symposium 2007*. Alexandria, VA: WateReuse Association.

Mitchell, V. G., et al. 2006. *Integrated Stormwater Treatment and Harvesting: Technical Guidance Report*. Monash University, Australia: Institute for Sustainable Water Resources.

Monterey Herald. 2004. http://www.montereyherald.com/mld/montereyherald/8620809.htm?template=contentModules/printstory.jsp 8may04. May 8.

Puget Sound Action Team. 2005. *Low Impact Development: Technical Guidance Manual for Puget Sound*. Publication No. PSAT 05-03. Tacoma, WA: Washington State University Pierce County Extension, accessed 07 November 2008, http://www.psp.wa.gov/downloads/LID/LID_manual2005.pdf.

Reardon, Rod, Graham Juby, and Randal Samstag. 2007. "Satellite reclamation plants-membranes vs. granular media filtration." *Proceedings of the Water Reuse Symposium 2007*. Alexandria, VA: WateReuse Association.

Sheikh, B. 2007. "Future potential for recycled water." *Proceedings of the Water Reuse Symposium 2007*. Alexandria, VA: WateReuse Association.

Texas Water Development Board. 2005. *Texas Manual on Rainwater Harvesting*, 3rd ed., Austin TX, http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf

Appendix C: Challenges and Water Technology Objectives for Sustainable Forward Operations

by Gary Gerdes, Construction Engineering Research Laboratory (CERL)

Sustainable Water for Forward Operations

Background

U.S. military forces today must have the capability to deploy to almost any location on earth, execute their mission successfully, and return to their home station. Recently, the mission of forward operations has evolved to include both combat operations and stability operations. In turn, base camps that support forward operations also evolve as the occupation endures. The transition of base camps generally occurs in three stages: (1) *Temporary*, during the first 6 months when hostilities occur and units often redeploy, (2) *Enduring*, starting after combat has ended and when stability operations occur (up to 60 months), (3) *Permanent*, when stability operations continue, and deployable facilities have been replaced by permanent facilities. At all stages, forward operations must be sustained.

"Sustainment" is not a new term to the Army. For centuries, large armies have waged wars and maneuvered against each other to gain a tactical advantage. At the same time, those armies had to maintain supply systems to sustain them. That "logistical tail" had to be efficient to obtain tactical advantage and ensure survival. Today, efficient sustainment is still important to the operations of the modern Army.

However, "sustainability" is a relatively new term, which generally refers to the conservation of the earth's resources. To the Army, sustainability is much more than a term used for political correctness. It is very important to minimize the amount of material that must be transported to a base camp (sometimes through hostile terrain) to minimize costs, in both resources and lives. In the base camp environment, "sustainability" is virtually the same as "efficient sustainment."

Constraints

The equipment used for the sustainment of forward operations must be suitable for base camp application, and must meet the following criteria:

- *Deployable*. Equipment must be designed to be shipped in standard CONEX containers, quickly set up, and easily relocated. It must not require significant site preparation, and it must be adaptable to various climates.
- *Expandable*. Equipment and systems must be capable to grow with the camp, and must be compatible with large and sudden changes in the camp population.
- *Durable*. Equipment must be able to withstand abuse from shipping and soldier operation.
- *Simple*. As an Army asset, equipment must be able to be operated and maintained by minimally trained soldiers or host nation personnel.
- *Energy Efficient*. Equipment should not place a significant burden on the energy resources of the base camp.
- *Minimal Force Protection Demand*. Equipment that requires hazardous chemical or fuel storage, that depends on services procured from outside the base camp or that depends on the local population, equipment that is vulnerable or requires special protective measures, all create a burden on force protection resources. Since movement of non-Army service vehicles through the camp perimeter is a security risk, technologies that do not require constant replenishing of consumables or frequent on-site manipulation are preferred.
- *Minimal Environmental Impact*. Sanitation equipment and systems must be designed with consideration of the effect that air, water, and solid waste emissions may have on the health of the soldiers, and with consideration for the cleanup that will be necessary following redeployment of the base camp.

Water for sustainment

The following passage is from 49^{th} Quartermaster Group website:

> Fuel and water are the two most important sustainment commodities on the battlefield. The ultimate weapon, the soldier, runs on water. Everything else runs on fuel.

A sustainable source of water is critical to any forward operation, and to the establishment of a base camp. Because mobile treatment equipment often does not provide water that is aesthetically conducive to drinking

(that appears clean and "tastes good"), bottled water is normally supplied. Drinking water is the most critical need, but water is also needed for ablution (AB) units, latrines, dining facilities, showers, and vehicle washing and maintenance.

According to a recent model developed for Army G4 to estimate in-theatre costs, when Army assets are used to provide water at a typical base camp in Iraq, the cost of that water is $15.30/gal.* Much of that cost is attributed to security for transportation. It is logical that an Army objective be to minimize the amount of water that must be transported to base camps. This objective may best be achieved by implementing technologies for on-site treatment and reuse, and possibly by exploiting non-conventional sources of water.

Most treatment equipment requires monitoring and adjustments during operation, and all require regular maintenance. As water/wastewater treatment processes have become more advanced and their performance improves, they generally require a greater skill level for operation and maintenance. Many advanced technologies, though successful at permanent Continental United States (CONUS) sites, may not be suitable for base camp application. Historically, biological processes require constant monitoring and adjusting, have long start up periods, are not easily adaptable to changing environments, and would be difficult to quickly shut down and redeploy without leaving a footprint behind. Biological processes do tend to be more energy efficient, which is important at base camps.

Conventional water/wastewater treatment processes produce some type of waste that contains the contaminants removed from the source stream. These wastes must be easily disposed, or if possible, reused. Sludge has been extremely difficult to manage at base camps, particularly wastewater treatment sludge. It can be argued that chemical or biological treatment technologies that produce a watery sludge are least appropriate for base camp application. However, that may not be the case if sludge can be used on-site.

The development of rapid-startup biological treatment systems is one of the research thrust areas coming out of the September 2007 "Workshop on Technology Approaches for Current and Future Base Camp Sustainabil-

* Edington, LTC Royce, HQDA, DCS G-4, *Sustain the Mission Energy and Water Cost-Benefit Tool*, presentation at the Joint Services Environmental Management Conference, May 2008, Denver, CO.

ity."* Another thrust area defined at that workshop includes both the advancement of membrane processes and riverbank filtration.

Potable water

Current practice

A sustainable source of water is critical to the establishment of a base camp. In urban scenarios, an existing treated water distribution system might be used to supply the camp. When treated water is not available, portable treatment equipment is often used to treat locally available surface or ground water. Water supply is also a security concern. Remote sources are subject to terrorist activity. Transfer of bottled water through the camp perimeter, as with the transfer/delivery of any material, is a security risk.

On-site treatment is done using the current inventory of Reverse Osmosis Water Purification Units (ROWPUs) (Figure E1). ROWPUs are gradually being replaced by the next generation Tactical Water Purification Systems (TWPS) and Light Weight Purifiers (LWP).

Figure E1. ROWPU in service at desert base camp.

* Dr. Kurt T. Preston, Army Research Office, *Technology Approaches to Current and Future Base Camp Sustainability.* Final Report of a workshop held 12-14 September 2007 in Raleigh, NC. Prepared by the Habitation Institute, North Carolina State University. http://ncsu.edu//kenan/ncsi/aro_base.html

Reverse osmosis water purification unit

Reverse osmosis (RO) water purification should be discussed within the context of other membrane technology. Membrane technology is used where conventional media filtration (e.g., pressure filters) is no longer viable to remove contaminants. Compared to conventional plants that include chemical addition, settling basins, and mixed media filtration, membrane treatment plants are more compact and more readily adaptable to deployment.

Mixed-media filtration normally removes 5–15 micron size contaminants and can be used in conjunction with RO to provide drinking quality water. The attractiveness of RO is that it removes ions, which other membrane technologies cannot do. Hence RO the only practical process used to desalinate water supplies.

ROWPU is used by water supply units at the divisional, Corps, and theater level to produce finished water. ROWPUs are deployed to provide the initial potable water treatment for base camps, and may rotate out in a 6–12 month timeframe along with the associated unit.

RO processes are normally complex and require trained operators who constantly monitor the operational process. The observation of filter efficiency, filter backwash, and other maintenance functions is necessary. The site must be designed for redundancy depending on water quality because RO capacity is a function of the total solids in the influent water, which itself may vary. ROWPUs must be dismantled and new membranes installed every 24–36 months. Finally, the units themselves will either contain a diesel pump or electrically driven pumps to boost pressure to 87 psi, which impart additional maintenance demands.

A disadvantage in the production of pure water is its associated corrosivity. RO Water Treatment Plant (WTP) water, due to nearly non-existent dissolved solids and alkalinity as $CaCO_3$, has virtually no buffering effect against pH swings. In the presence of CO_2, carbonic acid forms naturally, which drops the pH significantly. Depending on the storage components, it may be necessary to add alkalinity to the water following production at a ROWPU. Adding lime or other alkaline additives enhances taste characteristics and limits corrosivity.

ROWPUs are very versatile in operating in arid or humid environments. The units have the capability to operate in environments where tempera-

tures range from –30 °C to 50 °C. However, significant deterioration occurs to the membranes with water supply over 23 °C. The units themselves are best suited to enclosure in a building, removed from the elements.

RO units create backwash water from both the pretreatment filter and the membrane filters. The quantity of backwash created depends on influent water characteristics, but is typically a ratio of 25 percent of the throughput. This backwash could be discharged to a drainage ditch or stream with minimal environmental impact, unless ion levels are extremely high such as with brackish water. In this case, other discharge alternatives (e.g., land application or well injection) are recommended.

Problems

Testing conducted by the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) determined that three water quality parameters affect the acceptability of drinking water: chlorine, total dissolved solids (TDS) and temperature. Waters treated by reverse osmosis tend to be flat tasting due to relatively low TDS. Warm water was unacceptable for drinking, regardless of chlorine residual, though warm water tends to intensify the chlorine taste. When water was held at or below room temperatures, a chlorine residual as high as 2.5 mg/L was found acceptable. Water in the current theaters of operations tends to become hot quickly, which results in soldier refusal to drink. A Tri Service field water standard for temperature is 22 °C. Obviously, water can quickly become much warmer than that in Iraq. Anecdotally we are being told that it is easy to freeze bottled water, throw it in the back of a vehicle or backpack, and then move out for the day with a supply of water that stays cold longer.

Suggested approach to improve water logistics

It may be possible to obtain water from such innovative sources as: water vapor in the air, rain water, reuse of wastewater, urine, perspiration, and condensation of water vapor in engine exhaust. One gallon of fuel burned in an engine is said to produce enough water vapor to make 1 gallon of water.

It could be helpful to focus Research, Development, Test, and Evaluation (RDTE) efforts on a canteen (and 5-gal containers) that can keep water chilled or even provide some minimal chilling capability. Work should continue on reducing chlorine residual levels in water in ways that do not

increase risk from ingestion of pathogenic micro-organisms, and on examining alternative disinfectants and treatment devices on the outlets of water trailers.

The "Camel" water trailer is being developed to replace the M149A2 and M1112 water trailers and conceptually will be equipped with an integrated heater/chiller. According to recent briefings, the heater/chiller part of the design has unfortunately been cut for the near term fielding due to problems in its development and because the system is not able to meet weight/size requirements. Further research is needed to complete the heater/chiller capability.

With the fielding of the new TWPS and the LWP to replace the ROWPUs, it may be possible to change doctrine to allow reverse osmosis bypass under certain conditions. The membrane filter pretreatment on the new systems performs much better at physical separation of microbial pathogens than the multi media pre-filters on the ROWPUs. By allowing RO bypass, overall production from a water source can be increased by as much as 100 percent with the elimination of as much as 50 percent of flow to brine waste.

Bottled water

Current practice

Commercially bottled water seems to have become the primary source of drinking water for Soldiers, especially when away from the forward operating base (FOB). This is due to: (1) aesthetics — Soldiers believe bottled water tastes better than the usually warm, chlorinated ROWPU-produced water, and have the perception that clear plastic bottles imply purity, and (2) convenience — bottled water is easily carried and stored in vehicles. Since soldiers are more likely to drink from clear plastic bottles, they are more likely to remain hydrated in hot climates. Bottled water provides benefits in the forward theater that cannot be easily fulfilled by alternative methods, but these benefits come with costs and disadvantages.

Two quotes from 3ID (Mechanized) After Action Review OIF (Operation Iraqi Freedom) highlight the positive and negative impacts bottled water can have on operations:

> Bottled water is clearly the answer to the re-supply of drinking water. It speeds up LOGPAC (Logistics Civil Augmentation Program) times significantly and is more easily stowed in the interior of the vehicles. The

greatest advantage of bottled water was that it was easily replaced, unlike five-gallon water cans.

There was an apparent over-reliance on bottled-water during planning, preparation, and execution of OIF. A prime example of this trend surfaced during redeployment operations, when a major redeployment assembly area (RAA) had no bulk water capability to refill unit water buffalos or 5-gallon cans. The response from the staff on site was that "there was plenty of bottled water." This mindset was prominent throughout the TF. The Army needs to reinforce the use of the water buffalo, and consider bottled water as a luxury, rather than an entitlement. The demand for bottled water, in fact, incurred massive logistics requirements for shipping, packaging, and handling. This was true in the first Gulf War as well. Packaging was a consistent issue. Contracted bottled water frequently arrived in a condition that required individual handling by Soldiers.

Problems

Soldiers are generally accustomed to use disposable water bottles to the point where it has become their first choice even when it may not be the most efficient option. This now virtual requirement to provide commercially produced bottled drinking water has had significant drawbacks in terms of the logistics demands of purchasing, transporting, staging, and storing, and re-transporting the bottled water from the United States and friendly countries to the Area of Operation (AO).

It has been estimated that the cost of supplying bottled water to base camps in the Iraqi theater is more than $50/gal. Bottled water use continues in theater because of its convenience and perceived quality. The origin of bottled water tends to shift in the life of an operation from the United States to regional countries to sometimes even the host country. There are water quality concerns regarding water bottled commercially outside the United States (addressed in the CHPPM Information Paper No. 31-034). *
Bottling in-theater creates an upfront logistic demand and capital cost, which is soon compensated by the decreased cost of supplying bottled water and by the advantages of a shortened logistic tail. In-theater, bottling is not always a panacea. Using a local resource can create local shortages. Bottled water also creates a solid waste that must be managed. For exam-

* U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). 2003. *Use of Bottled Water for Deployment Support. Water Quality Information Paper No. 31-034*. USACHPPM, Aberdeen Proving Grounds, MD, 24 March 2003.

ple, plastic bottles were one of the largest and most costly components of the solid waste streams generated in the Balkans.

Solutions

A major and apparently successful effort at reducing the logistical stresses of purchasing bottled water was achieved by contracting the construction and operation of five contractor-operated “mobile” water bottling plants in Iraq. Those plants reportedly supply nearly all the required bottled water for deployed personnel in that AO. However, these plants were not truly mobile in nature and a significant logistics tail still exists to move water to smaller base camps. U.S. Central Command’s (CENTCOM) recent experiences with bottled water have led to recognition by both CENTCOM and the Combined Arms and Services Command (CASCOM) of the potential advantages of bottling and packaging water nearer the point of consumption.

In an effort to further reduce the demand on transportation assets in getting bottled water to remote or expeditionary units that have organic reverse osmosis (RO) units, the Program Manger for Petroleum and Water Systems (PM-PAWS) of CASCOM has proposed the acquisition of much smaller, truly mobile water bottling/packaging systems that could be embedded with those units. Thus, water could be packaged in plastic bottles at a Quartermaster-operated potable water point and picked up by or delivered to the various units serviced by that water point, reducing line-haul requirements to a minimum. Currently the PM-PAWS has acquired a mobile system from the German manufacturer Karcher, which is currently undergoing a proof of concept test at Camp Delta, Iraq. The USACHPPM is supporting the water quality testing and sanitary control and surveillance piece of the test.

The Program Executive Officer (PEO) Soldier (with support from CHPPM) is developing an individual soldier system consisting of the CamelBak, an inline filter, and disinfectant. Once fielded, it will better enable early entry and remote operations and should reduce the overall reliance on bottled water. The Natick Soldier Center has RDTE efforts underway on a thermoelectric water chiller capability, which, when deployed, could impact the use of drinking water treated on-site.

Recommendations

A suggested approach to improve use of bottled water includes:

- Educating soldiers on quality of bulk water.
- Continuing support of the PEO CamelBak point of use treatment system.
- Developing bottles that are degradable, or made of material that is easily reused.

Graywater

Treatment and disposal

Graywater is loosely defined as water generated by washing operations (i.e., laundries, showers, AB units, and washracks). It is thought to be less polluted and easier to treat than blackwater, which carries human and kitchen wastes. This may or may not be true, as at least one study has shown that graywater can have concentrations of BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) as high as municipal wastewater. However, the solids content in graywater is significantly less than blackwater, thus treatment of graywater produces significantly less sludge.

Recycling graywater

Force Provider and Quartermaster Corps laundry and AB support units have equipment that is designed to reuse wastewater. Deployable laundry equipment can store rinse water for reuse as wash water. A new deployable shower water recycle system developed at the Natick Soldier Center incorporates the TWPS technology. The system is housed in a TRICON ISO and will handle 12,000 gal/day from the Force Provider shower subsystem. Seventy-five percent of the shower water is recycled.

However, laundry and AB units at the more mature enduring and permanent camps are generally less sustainable. Segregation of graywater for separate treatment followed by recycle and reuse is not yet standard procedure at base camps. Washracks are designed on an individual basis, due to lack of standard design guidance.

CHPPM is engaging in a number of initiatives to evaluate the health implications and develop guidance and standards for reuse of various graywaters for showering. One study investigates reuse of ROWPU brine for

showers, while another involves the Force Provider shower water recycling system. There is already an Army Office of the Surgeon General (OTSG) standard for recycle of shower water, published about 5 years ago.* CHPPM is currently working with Aberdeen Test Center (ATC) and Developmental Test Command (DTC) to evaluate the shower water recycle system to ensure it can meet our criteria.

Addressing graywater problems

Technologies for graywater treatment and reuse have been studied, but are not fully implemented at base camps. Fully treated graywater could be reused at the original sources. Options for the reuse of graywater after minimal treatment have not been fully investigated. Minimally treated graywater could be reused for dust control, vehicle washing, evaporative cooling, or to satisfy the liquid requirements for solid waste processing.

Blackwater

Background

When base camps are first established, human waste is disposed by expedient methods such as burn-out latrines (Figure E2). The technology to design and construct these latrines dates back to the Vietnam era. The waste is "treated" by adding fuel to the wastes and setting it on fire. This method of handling human waste is unsafe, creates air pollution, and consumes valuable fuel. Improvements have been made to burn-out latrine technology. Figure E3 below shows an automated burn-out latrine.

As the base camp matures, burn-out latrines are usually replaced with chemical toilets, or latrines with flush toilets that drain to storage tanks or septic tanks. Because these facilities require a contractor to pump the waste, the contractor's vacuum truck must enter the camp frequently. This is a security risk and a burden on camp security personnel.

Structures with flush toilets draining to septic systems require leach fields. Leach fields are usually sited quickly with little thought given to soil suitability. Septic systems also have to be pumped. Septic systems are designed for specific flows. However, since base camp populations are not stable, flow surges often overload the systems.

* Office of the Surgeon General, DASG-PPM-NC, Memorandum, subject: Medical Standards on Water Quality Criteria and Treatment Practice for Recycle of Laundry and Shower Wastewater for Shower Use, 13 August 2004.

Figure E2. Waste burn-out activity with latrine in background.

Figure E3. Concept Design 2000 portable incinerating toilet with single commode stall.

Finally, when base camps are retrofitted for long-term use, wastewater collection and treatment systems are constructed. These may range from temporary above-ground piping that empties into a lagoon (Figures B4 and B5), to permanent buried piping that feeds into a package wastewater treatment plant (Figure E6).

Problems

With regard to waste "burn out," operational training is essential to avoid burn injuries and setting fire to close structures.

Army doctrine includes guidance on the use of lagoon treatment, a few of which have been constructed at base camps. While lagoons are a simple treatment, constructing them ties up valuable earth-moving equipment. After redeployment of the base camp, the lagoon becomes a restoration problem.

Figure E4. Dumping of blackwater in lagoon in Iraq (Source: M. Rabbe).

Figure E5. Facultative lagoon.

Figure E6. Sequencing batch reactor (SBR) and sludge tanks for brigade-size base camp.p.

Suggested Approach To Improve Blackwater Management

Sustainable technologies for latrine waste treatment that are sanitary, environmentally sound, are needed for mature camps. Water policies that encompass logistics, engineering, and medical criteria on the full range of recycle and reuse need to be developed. Update or cease the use of burn-out latrines. For temporary camps, alternatives are needed that are simple and require minimal operations and maintenance (O&M). Investigate commercial composting toilets and waterless toilets and urinals as quick fixes. Investigate ways to manage feces as a solid waste.

Treatment systems capable of taking varying loads with small footprints need to be developed or evaluated, such as membrane bioreactors, sequencing batch reactors or oxidation ditches. Develop innovative technologies/concepts such as: those that recycle latrine wastewater; beneficial use of human wastes and/or treatment sludge. Develop new technologies that allow source separation and possibly recycling of human wastes. Develop treatment technologies for specific waste generators such as latrines and DFACs. Standardize latrine waste management across all base camps. Reuse treated latrine wastewater on site. Use waterless latrines. Institute high temperature disposal similar to that used for medical waste.

The Way Forward

Technology Development Goals

Certainly there are many opportunities for the development of new or improved technologies—technologies that meet the goals and constraints of forward operations. General goals for base camps would include, but would certainly not be limited to:

- Treating and reuse wastewater at the point of generation.
- Incorporating cascade wastewater reuse wherever practical.
- Minimizing wastewater and solid wastes generated by mobile water treatment units.
- Developing deployable systems/methodologies to capture and use stormwater.
- Eliminating the disposal of all treatment process residuals.
- Discharging no liquid waste.

Management Initiative

Unfortunately, there is no single organization to provide oversight to the development and transition of technologies that will improve the sustainment of Army forward facilities. The many different “stovepipes” within the Army and Department of Defense (DOD) structure have created the situation where many efforts, sometimes conflicting, are ongoing without the authority of an umbrella agency. Hopefully this situation will be alleviated when the U.S. Army Maneuver Support Center (MANSCEN) stands up the Base Camp Integrated Capabilities Development Team (ICDT).

Role of the Workshop

It is the role of the Military Applications for Emerging Water Use Technologies Workshop to further define and augment the above goals. It is hoped that the workshop will identify emerging or state-of-the-art technologies that are ready for further development or demonstration, and will identify concepts for basic or developmental research that will lead to new water technologies with application to military forward operations.

References

49th Quartermaster Group (Petroleum and Water) website, http://www.globalsecurity.org/military/agency/army/49qm-grp.htm

Edington, LTC Royce, HQDA, DCS G-4. 2008. *Sustain the Mission Energy and Water Cost-Benefit Tool*. Presentation. Denver, CO: The Joint Services Environmental Management Conference, May 2008.

Jantzer, A. L., and G. L. Gerdes. 2005. *Base Camp Utility Technology Matrix*. ERDC/CERL TR-05-34. Champaign, IL: Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), November 2005.

Preston, Kurt T. 2007. *Technology Approaches to Current and Future Base Camp Sustainability*. Final Report of a workshop held September 12-14, 2007 in Raleigh, NC. Raleigh, NC: The Habitation Institute, North Carolina State University, http://ncsu.edu//kenan/ncsi/aro_base.html

Rabbe, M. 2007. *Environmental Struggles in Iraq* (For Official Use Only). St. Louis, MO: U.S. Army Corps of Engineers Environmental and Natural Resources Conference.

U.S. Army. 2003. Third Infantry Division (Mechanized) After Action Review, Operation Iraqi Freedom (For Official Use Only), July 2003.

U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). 2003. *Use of Bottled Water for Deployment Support*. Water Quality Information Paper No. 31-034, 24 March 2003, http://usachppm.apgea.army.mil/dehe/pgm31/IPs/IP31-034.pdf

Appendix D: Workshop Agenda

Military Applications for Emerging Water Use Technologies

Enhancing Water Access, Conservation, and Reuse Through Emerging Technologies

Workshop Agenda

Wednesday, November 12, 2008

2:00–2:15 p.m.	Welcome and Opening Remarks–Dr. Ilker Adiguzel, ERDC-CERL
2:15–2:40 p.m.	Emerging Issues in the Global Water Arena–Prof. Mark Shannon, University of Illinois
2:40–3:00 p.m.	White Paper Presentation–Challenges and Water Technology Objectives at Fixed Facilities–Mr. Bill Eng, HQ, ACSIM
3:00–3:20 p.m.	White Paper Presentation–Challenges and Water Technology Objectives for Forward Operations–Mr. Kurt Kinnevan, US Army Engineer School
3:20–3:35 p.m.	Break
3:35– 4:00 p.m.	Water Technology Research at Sandia National Laboratories–Dr. Mike Hightower, Sandia National Laboratory
4:00–4:25 p.m.	Water Technology Research at AwwaRF–Dr. Chris Rayburn, AwwaRF
4:25–4:50 p.m.	Water Technology Research at WaterCa.m.PWS – Prof. Mark Shannon, University of Illinois
4:50–5:15 p.m.	DARPA MANTRA Program–Dr. Cindy Daniell, DARPA, given by Kurt Preston, ARO
5:15 p.m.	Adjourn for Dinner

Thursday, November 13, 2008

8:00 - 8:15 a.m.	Morning Welcome and Objectives for Breakout Sessions
8:15 –10:00 a.m.	Breakout Session–Technology Needs for Enhancing Water Supply from Traditional and Alternative Sources (Facilitators)
10:00 -10:15 a.m.	Break
10:15–11:00 a.m.	Report Findings from Breakout Sessions (15 min. per group)
11:00–11:30 a.m.	Shuttle to University Campus
11:30 a.m.– 12:30 p.m.	Lunch and Keynote Presentation by BG Jeff Talley (Live VTC) Introduction by Associate Dean Michael Bragg, University of Illinois
12:30–2:15 p.m.	Facility Tour: WaterCa.m.PWS Civil & Environmental Engineering Department Virology Laboratories
2:15–2:45 p.m.	Break and Return to Hotel
2:45–4:45 p.m.	(Break 4:00–4:15 p.m.) Breakout Session–Technology Needs for Facility-Wide Sustainable Water Management (Facilitators)
4:45–5:30 p.m.	Report findings from Breakout Sessions (15 min. per group)
5:30 p.m.	Adjourn for Dinner

Friday, November 14, 2008

8:00 - 8:10 a.m.	Morning Welcome and Objectives for Breakout Sessions
8:10–8:40 a.m.	Brief Overviews of Technology Dr. Paul Armistead, Office of Naval Research, MAJ Tom Timmes, U.S.Army/Pennsylvania State University, Dr. Jay Dusenbury, US Army TARDEC
8:40–11:00 a.m.	Breakout Session–Technology Needs for Forward Facilities and Unique Environments (Facilitators)
10:00–10:15 a.m.	Break
11:00–11:45 a.m.	Report-out From Breakout Sessions (15 min. per group)
11:45–12:00 p.m.	Closing Remarks and Next Steps
12:00 p.m.	General Meeting Adjourn
12:00–2:00 p.m.	Volunteer Report Authors' Meeting

Appendix E: List of Attendees

Attendee	Organization
Larry Isaacs	AFCEE/TDNQ
David Sheets	Army Environmental Policy Institute (AEPI)
Kurt Preston	Army Research Office (ARO)
Chris Rayburn	American Water Works Association (AWWA) Research Foundation
Rob Renner	AWWA Research Foundation
Saied Delagah	Bureau of Reclamation
Kofi B Bota	Clark Atlanta University
Eric Mintz	Clark Atlanta University
Tzahi Cath	Colorado School of Mines
Jay Garland	Dynamac Corporation
Hal Balbach	Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL)
Ilker Adiguzel	ERDC CERL
Susan Bevelheimer	ERDC-CERL
Deb Curtin	ERDC-CERL
Patrick Edwards	ERDC-CERL
Gary Gerdes	ERDC-CERL
Bill Goran	ERDC-CERL
Elisabeth Jenicek	ERDC-CERL
Melixa Rivera-Sustache	ERDC-CERL
Rik Scholze	ERDC-CERL
Eddy Smith	ERDC-CERL
Annette Stumpf	ERDC-CERL
Hany Zaghloul	ERDC-CERL
Ingo Haeser	Federal Office of Defense Technology & Procurement
Gary Jacks	HQ, Air Force Civil Engineer Support Agency (AFCESA/CEOA)
Gary Nault	HQ, Air Combat Command/A7AN
William Eng	HQ, Army Office of the Assistant Chief of Staff for Installation Management (OACSIM)
Bill Sproul	OACSIM
Mal McLeod	Headquarters, U.S. Army Corps of Engineers (HQUSACE)
Carol Wong	Hughes Associates, Inc. / Research, Development, and Engineering Command (RDECOM)
Vinod Patel	Illinois Sustainable Technology Center
William Venable	NAVFAC Engineering Service Center
Paul Armistead	Office of Naval Research
Mike Hightower	Sandia National Laboratories
Mark Rigali	Sandia National Laboratories
John Hall	SERDP/ESTCP

Attendee	Organization
Alou Rice	U. S. Army Corps of Engineers
Jeffrey Talley	U.S. Army
William Fifty	U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM)
Todd Richards	USACHPPM Water Supply Management Program
Rebecca Wingfield	U.S. Army Engineering School
Kurt Kinnevan	U.S. Army Engineering School
Scott Hill	U.S. Army Environmental Command
Thomas Bradford	U.S. Army Garrison
Riki Young	U.S. Army Garrison, Fort Hood
John Wellborn	U.S. Army Garrison, Fort Gordon
James Dusenbury	U.S. Army Tank Automotive Research, Development & Engineering Center (TARDEC) Force Projection Technology Area
Tom Timmes	U.S. Army/Penn State University
Herb Fredrickson	U.S. Environmental Protection Agency (USEPA) National Risk Management Research Laboratory
Michael Bragg	University of Illinois at Urbana-Champaign
John Georgiadis	University of Illinois at Urbana-Champaign
Charlie Werth	University of Illinois at Urbana-Champaign
Wei Zheng	University of Illinois at Urbana-Champaign
Bruce Hinds	University of Kentucky
David Hamman	WaterCAMPWS University of Illinois at Urbana-Champaign
Brian Pianfetti	WaterCAMPWS University of Illinois at Urbana-Champaign
Mark Shannon	WaterCAMPWS University of Illinois at Urbana-Champaign

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14. ABSTRACT
This first ever Military Applications for Emerging Water Use Technologies workshop gathered Department of Defense (DOD), academic, trade association, and other government subject matter experts to explore the topic of water for the military at the installation and forward operating levels. The goals of this workshop were to share information, spread visibility on current efforts, explore the potential of existing, emerging, and future technologies and other options for military installations and potentially identify potential thrust areas where demonstrations and future research can be focused. The military has many water-related requirements and goals that are applicable to DOD installations and forward facilities, as exemplified by the fiscal year 2007 (FY07) Army Environmental Requirements and Technology Assessments (AERTA, included in Appendix A to this report), which identified sustainable water usage as the top-ranked environmental requirement for the Army. Workshop participants concluded that there are a great number of issues and constraints impacting water use at both forward and fixed installations and large potential for research and demonstrations that can be used to reduce the "water footprint" of the military and migrate towards more sustainable use of this vital resource.

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